THE SOIL SCIENCE SOCIETY OF FLORIDA

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PROCEEDINGS
VOLUME II
1940

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Interim Meeting of the Society
Tampa
April 2, 1940

Second Annual Meeting of the Society
Gainesville
May 29-30, 1940

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1940-1941

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ACKNOWLEDGMENTS

The entire membership is deeply indebted to the Officials of the Florida State Horticultural Society for their cordial cooperation in developing the Interim Meeting on soil reaction in Tampa on April 2; also to the Officials of the Tampa Terrace Hotel for their efficient handling of the space and other requirements for same.

We are likewise greatly indebted to President John J. Tigert and the Administration of the University of Florida for the use of the auditorium in the Chemistry Building and the General Assembly Room in the Student Union Building for the various symposia, lectures, and other functions that comprised the Second Annual Meeting of the Society held on the Campus of the University on May 29 and 30.

It is our privilege, furthermore, to express the real benefit and pleasure found in holding our Second Annual Meeting on the Campus at the same time as that of the Florida State Florists' Association. The interest and enthusiasm of this group is always inspiring and helpful.

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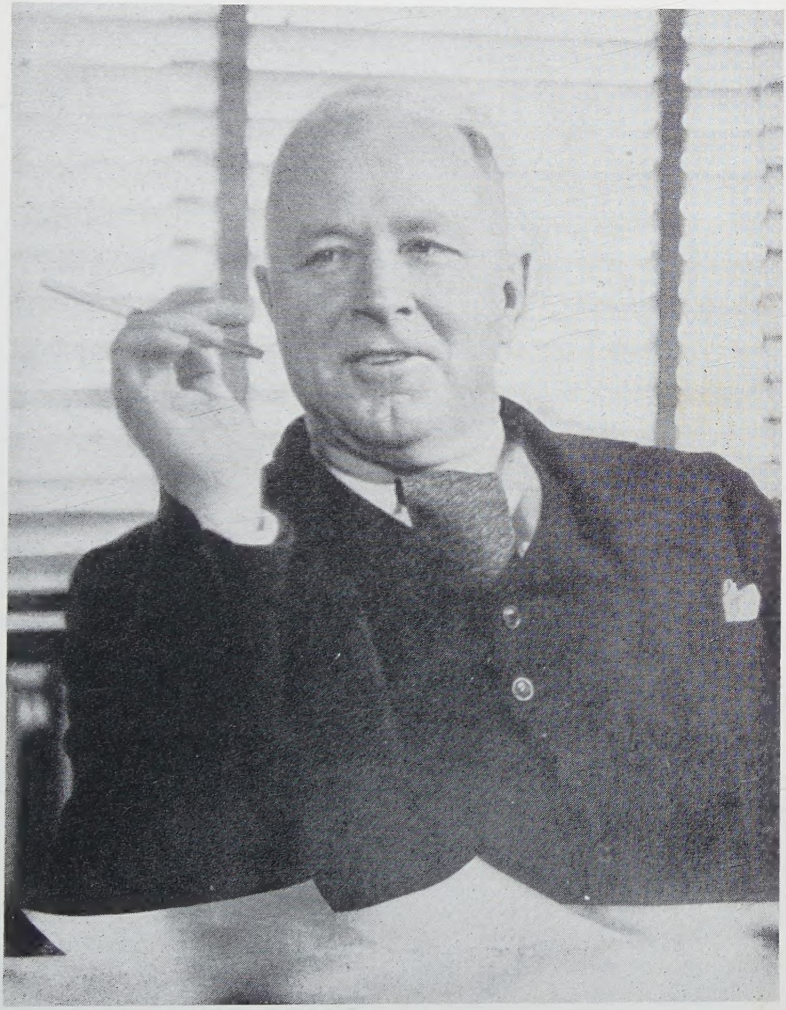


HONOR GUEST

Dr. H. H. Bennett, Chief of the Soil Conservation Service, as guest of the 1940 meetings of the Society, was able to give only a brief talk on the evening of the 29th at the time of the dinner and smoker, through the fact that he had practically lost his voice in the course of a strenuous trip for the Government through Mexico, from which he had returned only shortly prior to the Soil Science meetings. His remarks dealt largely with Tropical American Soils, and are outlined briefly in the report of the Tropical Soils Committee of which he is Chairman.

MICROBES IN A CHANGING WORLD

SELMAN A. WAKSMAN

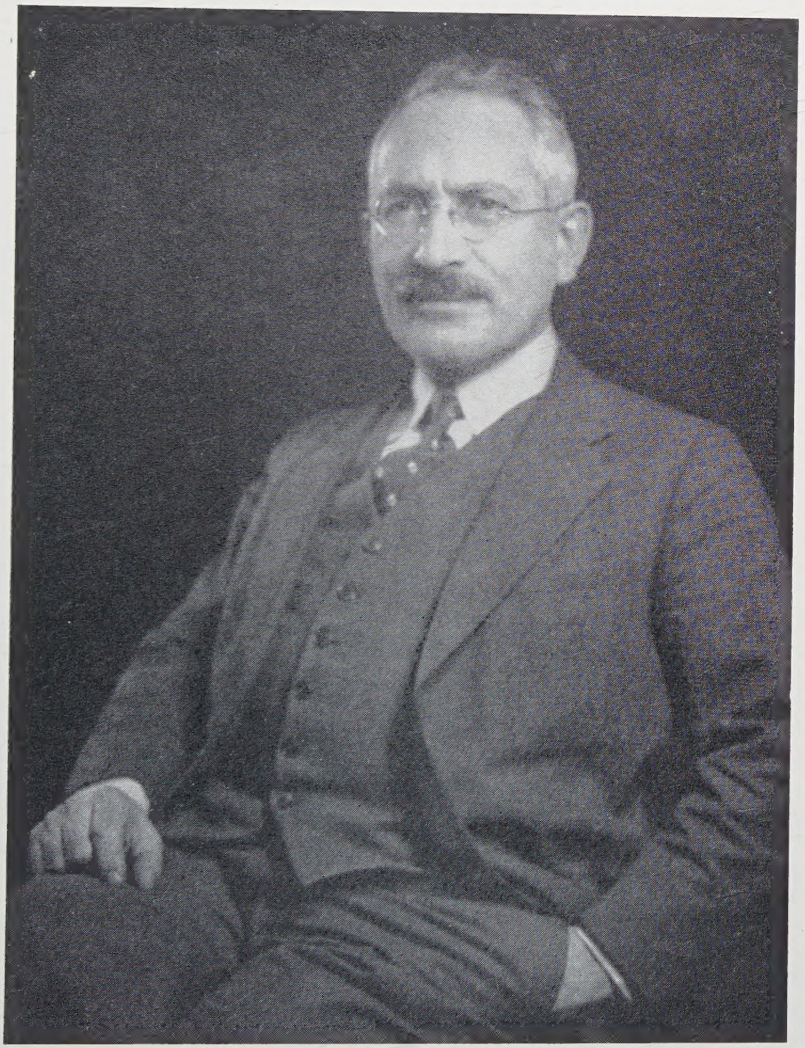
In this address emphasis was laid upon the changing conceptions of microbes from the early stages of the development of microbiology to the present time. The following three citations may suffice to emphasize these conceptions:

Lavoisier stated, during the last part of the eighteenth century, that "Plants thrive at the expense of the air that surrounds them, of the water, and of the mineral kingdom from which they obtain materials essential for their organization; animals obtain their nutrition from plants, or from other animals also nourished by plants, so that matter thus produced is always formed from the air and the mineral kingdom; finally, the processes of fermentation, putrefaction and combustion continuously return to the air and to the mineral kingdom those principles which have been removed by plants and animals. By what processes does nature bring about this marvelous cycle between the three kingdoms?"

Eighty years later Pasteur completed the understanding of this process by emphasizing that "The destruction of the dead organic matter is one of the necessities for the continuation of life. If the debris of plants that ceased living, as well as of dead animals, were not destroyed, the surface of the earth would become covered with organic matter, and life would become impossible, because the cycle of life could not be completed."

In continuing his address, the speaker stated that "There is increasing appreciation of the probability that nature harbors many unknown organisms, and that we still have quite incomplete knowledge of the activities, potentialities and importance of many well-known microbes. We are at the beginning of a period of domestication of a new type of organism, which may help in combating the deadly enemies of man. Micro-organisms represent in this respect a totally different branch of biology in relation to human welfare. . . . We are finally approaching a new field of domestication of micro-organisms for combating the microbial enemies of man and of his domesticated plants and animals. Surely, microbiology is entering a new phase of development."

The complete address was published in the *Scientific Monthly*, November, 1940, pp. 422-427.



GUEST SPEAKER

Dr. Selman A. Waksman, Soil Microbiologist at Rutgers College and the New Jersey Agricultural Experiment Station, has enjoyed an international reputation in the field of soil microbiology for a number of years. His address, "Microbes in a Changing World," given on the evening of May 29, following a dinner and smoker, is summarized briefly on the previous page. His discussion of "Peat and Its Uses" is a part of the symposium on organic matter and appears on page 131 of this Proceedings.

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INTERIM MEETING

Tampa Terrace Hotel, Tampa, Florida, April 2, 1941
2:00 P. M.

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A. Symposium: Soil Reaction as a Basis for Certain Land Management Practices

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INTRODUCTION

R. V. Allison

This symposium on soil reaction has been called as an interim meeting of the Soil Science Society in view of the rapidly growing interest that is to be found among a wide variety of growers in the relation of this factor to the normal growth of plants. It is particularly timely, and in fact highly desirable just now, since the Agricultural Adjustment Administration has already begun to seriously explore the possibility of incorporating appropriate applications of lime or dolomite as a definite part of its conservation program. The importance of a reasonably convenient "yardstick" to ascertain the need of a given soil for such treatment is obvious, therefore, and especially so since workers checking on compliance of the grower with other aspects of the program would in many instances be in an excellent position to take appropriate samples for the purpose of having reaction determinations made on them once an adequate procedure for taking and submitting these samples is placed in their hands.

In times past, our experience with excesses of lime in the soil have not been too pleasant whether they occurred there naturally or by virtue of a too heavy application on a field treatment basis. Unfortunately, under those conditions, lime came to be regarded as a "poison" by many and developed quite a bad reputation in consequence of its adverse effect on plant growth under such circumstances. The high lime content of our marl soils, of the Parkwood and certain other mineral types and some of our "sweet" or alkaline peats and mucks that have been even moderately burned, is of course, quite well known.

By the late twenties, however, we had come to understand that the poor growth of many plants in high lime soil environments is due largely to the inavailability of certain trace elements. notably manganese and, in some cases, zinc and boron, that is developed by such highly alkaline conditions.

Thus the control we can now exercise over what were formerly recognized as adverse effects from too much lime might well raise the question of whether certain qualities in the plant, or the fruit thereof, might not be improved in one way or another by a high-lime soil environment. Such a question of course remains for the future. We are more directly concerned at this time with the development of a routine whereby soil samples and related field data can be collected and the reaction determined in a systematic way for any assistance this information may lend in directing a liming program for a particular area. Just what the optimum reaction, or lime content of a given soil type shall be for a particular plant remains to be determined for the most part, especially when various elements of quality are brought into the picture as suggested above. With the exception of the so-called acid-loving or lime-loving plants, however, a reaction range of pH 5.8 to 6.3 is found to satisfy a wide number of species and varieties quite well.

As opposed to the question of too much lime and too high a reaction (pH) we must, of course, also keep in mind the dangers of a soil reaction that is too acid. Under such conditions, many elements, including the trace elements, tend to go into solution more quickly and, in consequence, are readily leached out of the soil with the drainage waters. This condition can be brought about by a variety of causes including a too continuous use of acidic fertilizers or the use of sulfur (as in disease and insect control programs) in appreciable quantities. The corrective measure is, of course, a judicious use of lime.

In all of this it is felt that there is one principle that should be kept in mind, above all others, namely, that it will always be much easier and less expensive to put on a little more lime the following year than to "remove" a portion of that which has already been applied. This latter, of course, can be accomplished in fact only by the use of supplementary treatments with requisite trace elements or acid bearing materials which will tend to counteract the effects of the excess of lime.

You will note from the program whch has been handed you that the various topics for discussion have been arranged with as much continuity as possible. Thus we are to start with a discussion of factors affecting the sampling procedure by Messrs. Volk and Peech and then take up the routine of collecting and preparing the samples for shipment to the laboratory along with requisite field information which will be presented by Messrs. White, Ayers, and Norris. Following this phase, Mr. Carrigan will give a comprehensive review of the laboratory procedure to be used in making the reaction determinations, since quite a number of you are interested in the details of this operation. However, the crux of the whole matter, in a way, is properly putting the reaction values to work once they have been made available to the County Agent or the grower. This will be outlined by Messrs. DeBusk and Rogers.

Thus this special symposium on soil reaction has been developed to see if a routine of sampling and field reporting can be evolved which will serve as a satisfactory criterion for field recommendations as to lime requirements. It is our sincere hope that you will not feel that undue emphasis is being given to soil reaction, since a discussion of

the limitations of the reaction factor is also a very definite responsibility of this program. Further than this, it is the present thought to expand the work to be done on these soil samples to include other elements of soil fertility as rapidly as satisfactory laboratory procedures can be developed for the purpose and adequate assistance is made available to do the work.

The interest and support of the State officials of the Agricultural Adjustment Administration as well as those of the Agricultural Extension Service in this effort is greatly appreciated. We are also indebted to the officials of the State Horticultural Society for their interest and cooperation in the organization of this program in a fully coordinated manner with those of the annual meetings of that Society which start this evening and continue for two full days in this same hotel.

The various speakers will now present their material in the sequence outlined in the program. We are indeed glad that Mr. H. G. Clayton, State Administrative Officer of the Agricultural Adjustment Administration, has found it convenient to be present and lead the general discussion.

FACTORS AFFECTING THE SOIL SAMPLING PROCEDURE

GAYLORD M. VOLK* AND MICHAEL PEECH*

Proper sampling of soils for chemical or physical analysis is extremely important. It is often the weakest link in the chain of factors determining the value of an estimation of soil fertility. Soil samples must be truly representative of the area from which they are taken and to which the analytical data will subsequently be applied. Each should consist of a definite horizon or layer of soil which is fairly uniform throughout its depth rather than being a mixture of layers of different textures. Samples should be taken with clean tools, put into clean containers and submitted promptly for analysis before the changed environment affects the solubility of nutrients or alters other characteristics of the soil. It is preferable that they be air-dried before placing in containers for shipment.

SOIL SAMPLING TOOLS AND THEIR OPERATION

Numerous types of tools have been designed for the purpose of taking soil samples. Some are highly specialized for taking deep samples comparatively free from contamination with the surface soil, while others are very simple and designed primarily for sampling surface soils or shallow subsoils. Sampling tools, in general, may be divided into three classes as follows:

1. Shovel type—shovels, trowels, spades, spoons.
2. Augers—wood bit, cylindrical, post hole, sheathed.
3. Tubes—King (California), open sided, plain cylinder.

Three types of the sampling devices referred to above are shown in Figure 1.

In taking soil samples with the shovel or trowel type of instrument a clean vertical cut should be made down the side of a hole dug to the proper depth. The sample should be obtained by making a vertical cut down the cleaned surface so as to remove a section of uniform thickness for the entire depth of the layer which the sample is to represent.

The ordinary wood auger (B, Fig. 1) is satisfactory for taking samples of comparatively moist soil. Dry soils will not stay in the auger. Cylindrical, post hole, or sheathed augers are more satisfactory for use in dry soil. In sampling surface soils the auger is sunk to the desired depth and the entire sample of soil clinging to it upon removal used to make up the sample. For greater depths the top two inches of soil brought out by the auger should be discarded and the remaining soil put into the sample. The depth being sampled can be ascertained

* Soil Chemist, Florida Agricultural Experiment Station, Gainesville and Citrus Experiment Station, Lake Alfred, respectively.

by marking the handle of the auger at six inch intervals. Augers do not give samples that are as free from contamination when used for subsoil sampling as do either the shovel or the tube type of instrument. This is not particularly important when sampling for mechanical analysis, but is a very important consideration when sampling for nutrients which are being applied to the surface as soil amendments. Thus in the case of sandy subsoils, with low exchange capacities, contamination by lime applied to the surface often leads to misleading results. In a similar way exposure of unlimed top soils to marl from the subsoil should be carefully avoided. Further than this, care should be used at all times to prevent contamination from mixing cloths, dishes, or sieves that have had previous use for samples differing widely in reaction or fertility.

The tube type of instrument is being used more widely at present than at any time in the past. These instruments are all based on the principle of forcing a cylinder into the soil by direct vertical pressure. In almost all types the soil rises in a column as the tube penetrates the soil. The King or California tube (A, Fig. 1) has a constricted tip to

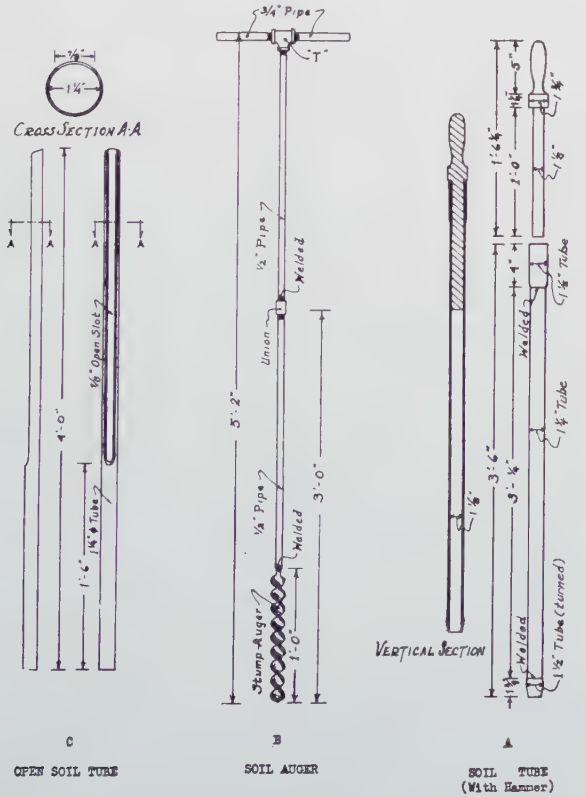

Figure 1.

cut a soil core slightly smaller than the inside diameter of the tube so that the soil core will rise with as little friction as possible and will not compact within the tube. It also has an outside bulge just above the tip so as to make a hole slightly larger than the outside diameter of the tube to facilitate withdrawal. The sample is removed by inverting the tube and the core cut into sections representing the various depths.

Another type of tube (C, Fig. 1) consists of a straight-bore pipe provided with a narrow opening along the side that permits observation of the entire core. This slit also prevents the soil from compacting within the tube. In this way the various sections representing depths to be sampled are pushed out of the tip of the tube in the reverse order of depth. This type, usually made of stainless steel, can be designed in a variety of ways with respect to the opening and cutting edge. For greater strength, a full cutting band about an inch wide can be left below and the opening itself made in the form of a long triangle with the base at the cutting end. A tube of this type is especially convenient for shallow sampling in certain soils, including loose sands when they are sufficiently moist for the instrument to retain the sample.

A special type of open-sided tube has a closed point and a window in the side. The window is covered by a shutter which opens and closes by a twist of the tube. This tube is used primarily for taking deep samples that must be exceptionally free from contamination. The tube is driven into the ground with the shutter closed. A turn in one direction opens the shutter and continued turning scrapes a sample of soil into the open window. Reversing the direction of turning closes the shutter so that the tube can be withdrawn without contamination of the sample.

DETERMINING THE SOIL AREA TO BE REPRESENTED BY SINGLE OR DUPLICATE SOIL SAMPLES

The first problem in the general sampling of any block of land is that of dividing it into sub-areas that are uniform with respect to soil texture, organic matter content, native vegetation, drainage, and past fertilizer practices. If sub-areas so outlined are large, further arbitrary division may be advisable. The size of an area to be represented by one sample is entirely dependent upon the degree of detail desired, and the purpose for which the sample is taken. In special instances it may be desirable to sample very small areas such as would be the case where the analysis of the soil from areas supporting abnormal plant growth is to be compared with that from the surrounding area supporting normal growth. The samples should be properly labeled for ready identification in the laboratory.

SAMPLING OF THE SURFACE SOIL OR PLOW DEPTH

The surface soil generally may be considered as that turned over by normal tillage operations on plowed lands or as the six-inch surface layer of soil on unplowed or lightly tilled lands, unless the soil varies markedly in texture or lime content within this depth such as would be the case where a shallow surface soil overlies a subsoil of markedly dif-

ferent texture or where shallow marl can be found within less than six inches below the surface. Under such conditions the surface soil should include only the uniform surface layer, and the underlying layer should be sampled according to instructions given for sampling subsoils.

Each sample of surface soil should consist of a mixture of portions of soil taken from several locations within the area in question. Portions of soil from at least ten locations within the area to be sampled are considered essential to make up a representative sample. The same amount of soil should be taken from each location, the portions thoroughly mixed together on a piece of tough paper or clean cloth or canvas, and approximately a pint of the mixture saved to be submitted as the surface sample from the area. The sample should receive the number of the area and the depth to which it was taken: i.e. 0-6″ indicating that the layer occurred between zero and six inches. For greater accuracy and as a check on the degree to which the first sample represents the area from which it came it is often desirable to take a second sample from the same area, but from another set of ten different locations. The first sample should then receive an additional "A" in its area number, and the second sample the area number plus a "B": i.e. Area 1, 0-6″, A; Area 1, 0-6″, B.

Row crop fields should be sampled by taking soil portions from the row or hill if the land is already bedded or planted. It should cut through the fertilizer band if determinations of nutrient element levels are desired but should not intersect the band if reaction only is to be determined. Special sampling procedures, such as those discussed below for citrus groves, should be used wherever spray programs such as those practiced on tree crops are followed. For broadcast crops, pasture areas, or unbedded or unplanted rowcrop areas, the soil portions going to make up the sample should be taken at random from the area.

SAMPLING OF THE SUBSOIL

Subsoil samples are seldom taken for reaction measurement except in particular cases where such are thought to be of special significance. Where samples are thought to be of interest, they are taken by arbitrary depths such as 6-12″ and 12-18″ if a fair degree of subsoil uniformity exists. At least ten individual cores of subsoil of any given depth are taken and mixed together as in the case of the surface sample. The subsoil sample may be conveniently taken simultaneously with the surface sample. Where distinct horizons of marl, clay, or organic matter occur they should be sampled individually for laboratory identification and analysis. Each sample should contain the area number, a location letter, and the depth from which it came: i.e. Area 1, 6-12″, R; indicating that the sample came from "R" location in area No. 1, and that the top of the layer began at six inches and that the bottom was at twelve inches. Extreme care should be taken to prevent contaminating the subsoil samples with the surface soil, or the surface samples with the subsoil as, for instance, where the former may be low in exchange capacity and the latter high in such a component as lime.

TIME OF SAMPLING

Time of sampling is largely determined by the crop to be grown and the fertilizing and liming program to be followed. For general sampling it is preferable to take samples a period of time prior to fertilizing and planting just sufficient to allow analyses to be completed and recommendation made. At least six months should elapse before sampling after an application of soil conditioner such as lime has been made. Samples may be taken at any time of the year for the purpose of investigating soils upon which abnormal plant growth exists. It is preferable not to take samples immediately after heavy leaching rains or during the latter stages of extended dry periods except where the effect of such a period on soil fertility is being studied. Samples should not be taken immediately after turning under a green manure crop. A complete picture of soil reaction fluctuation requires the sampling of the same area periodically throughout the year.

In checking the effect of an application of any basic material sufficient time should be allowed for the reaction to take place in order to be assured that the maximum pH value has been attained. It should be remembered, furthermore, that the various basic materials commonly used to correct soil acidity decompose at different rates. Other factors, such as initial soil reaction, soil type, cultivation, fertilizer practice, and seasonal conditions, influence the rate of reaction between the basic material and the soil. Unless these factors are taken into consideration and sufficient time is allowed between applications, more basic material is likely to be applied than is either necessary or safe. In the case of dolomite, about one year should have elapsed between the time of the application and the sampling. The best and most convenient time to take soil samples in citrus groves is perhaps in the early fall preceding the fertilizer application.

SOIL SAMPLING UNDER CITRUS GROVE CONDITIONS

In view of the fact that the plans of the Agricultural Adjustment Administration for the liming program referred to above are further along for citrus growers than for any other group, more emphasis will be given to sampling under grove conditions. In fact it has been the thought to work this through in a rather complete manner with the idea of making of it something of a model to be followed as closely as may be properly done for other crops later.

Soil Variation Relative to the Distance from the Trunk of the Tree

One of the difficulties encountered in obtaining a representative soil sample in citrus groves arises from the fact that there exists a considerable variation in pH and chemical composition of the soil with respect to the distances from the trunk of the tree. This is especially true where basic materials have been applied recently. The soil within the area of the tree spread is, with but few exceptions, more acid than that outside the tree spread or in the centers of the checks (center of square or rectangle formed by four adjacent trees). Usually the pH value of the soil increases gradually with the increasing distance from the trunk

to the periphery of the tree but with very little change beyond that point. In an attempt to arrive at the factors responsible for this soil variation, an experiment was conducted in collaboration with Mr. W. L. Thompson, Entomologist of the Citrus Experiment Station, to study the effect of sulfur sprays incident to pest control on the soil reaction and chemical composition. In the experimental grove used in this study, trees have been sprayed with different materials about four times a year over a period of five years. Dolomite was broadcast over the entire area from trunk to trunk at the rate of 700 pounds per acre during each of the fourth and fifth years. At the end of the five-year period soil samples were taken to a depth of 6 inches at the following distances from the trunk of the tree: 1, 3, 6, 9, 12 and 18 feet. The soil sample from each of the six locations above consisted of 8 borings per tree distributed around the tree, and four trees were sampled making a total of 32 borings for each composite sample. The analytical data are listed in Table 1, and the results of pH determinations are plotted in Figure 1 to show the increase in pH with the increasing distance from the trunk of the tree.

TABLE 1.—Variation in pH and Chemical Compositions of Norfolk Fine Sand, 0-6 Inches, with Respect to the Distance from the Trunk of the Tree as Affected by Sulfur Sprays.

Sulfur Spray Program	Distance from Trunk[1]	pH	Exchange Capacity[2]	Lbs. per Acre-Six-Inches					
				Exchangeable Bases				Phosphorus	
				Ca	Mg	K	Mn	Acid Sol[3]	Water Sol.
Check	1	4.50	2.40	110	18	23	4.7	42	7
	3	4.75	2.28	187	22	31	4.8	86	8
	6	5.50	2.50	452	63	56	6.7	340	16
	9	6.05	2.50	535	97	81	6.6	372	18
	12	5.85	2.04	387	80	70	6.7	288	18
	17.7	5.70	1.94	323	77	76	10.0	198	14
Lime-sulfur	1	4.25	2.04	103	10	19	3.6	42	7
	3	4.50	2.04	180	14	23	5.8	102	8
	6	5.25	2.22	380	41	51	8.2	314	16
	9	6.00	2.54	580	84	82	8.2	405	17
	12	6.00	2.30	477	93	82	9.7	362	20
	17.7	5.85	1.88	329	75	68	10.0	236	14
Wettable Sulfur	1	3.65	2.50	26	9	19	3.3	39	10
	3	3.75	2.52	71	7	16	3.3	70	15
	6	4.55	2.58	232	30	50	10.0	240	22
	9	5.45	2.74	484	75	92	9.4	304	20
	12	5.70	2.54	470	81	89	11.0	330	21
	17.7	5.60	2.50	406	89	94	13.5	266	16

[1] Distance of 17.7 feet from the trunk represents centers of checks, the average radius of tree spread was 8 feet.

[2] Exchange capacity in milliequivalents per 100 grams.

[3] Phosphorus soluble in .002 N H_2SO_4 according to method of Truog.

As shown in Figure 1 the soil under the trees sprayed with wettable sulfur was more acid than that under the trees sprayed with lime-sulfur, whereas the soil under the trees sprayed with lime-sulfur was more acid than that in the check plot. It will be noted, however, that the soil in the check plot showed the same increase in pH with increasing distance from the trunk of the tree as that in the lime-sulfur and wettable sulfur plots. This would indicate that in addition to sulfur sprays there are other contributing factors responsible for this condition, among which may be mentioned, the method of fertilizer application, preponderance of roots and consequently greater absorption in the area within the tree spread, as well as difference in soil moisture conditions and in the extent of cultivation between the area under the tree and that outside the tree spread. The amounts of exchangeable calcium, magnesium, potassium, and manganese, and readily soluble phosphorus are correspondingly reduced with the increasing soil acidity as shown in Table 1. In sampling grove soils, therefore, for the determination of pH and other constituents, the practice of compositing soil cores or borings taken in the area underneath the tree with cores taken outside the tree spread is to be discouraged as the results obtained on such a sample are not only difficult to reproduce upon resampling but are also hard to interpret.

Depth of Sampling

The depth to which the sample should be taken is another important factor which warrants careful consideration. Experiments conducted at the Citrus Experiment Station over a period of four years on the effect of annual applications of varying amounts of different basic materials on a Norfolk fine sand have shown that while the pH value of the surface

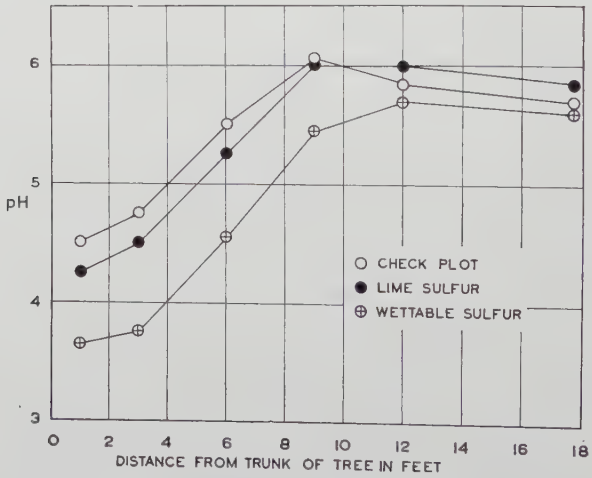

Figure 2.—Variation of soil reaction with the distance from the trunk of the tree as affected by sulfur sprays. The last point, at 17.7 feet, represents the center of the check; the average radius of tree spread was 8 feet.

layer, 0 to 6 inches, has been increased from 5.0 to 7.0, the pH value of the subsoil, 6 to 12 inches, has not been affected appreciably, indicating little downward movement despite the porous nature of the soil. It would seem that the surface sample of light sandy soils should not be taken to a depth greater than 6 inches in consideration of the following factors: (1) Downward movement of basic materials is slow; (2) effective depth of cultivation is seldom over four inches; (3) natural change between the surface soil and the subsoil occurs at five to six inches; (4) there is a marked difference in exchange capacity as well as in the exchangeable base content between the surface soil and the subsoil; and (5) the majority of the fibrous feeder roots are in the surface layer. It is not advisable to "scrape away two inches of the top soil" before taking the sample. Subsoil samples, if desired, may be taken either from 6 to 12 or 6 to 18 inches.

Hammock soils are more variable than light sandy soils and consequently greater care must be exercised in selecting areas to be sampled as well as in compositing the individual cores in order to prevent mixing the surface soil with the marl layer which lies at varying depths below the surface layer. For this reason hammock soils should not be sampled to any arbitrary depth but rather according to soil horizons. However, where there is no significant change in the soil profiles the surface samples may be taken to a depth of 10 inches. In either case, the depth of the surface and subsoil sample, if the latter is taken, should be recorded.

Recommended Procedure

Sample A (area outside the tree spread)

By means of a trowel or preferably a tube ½ to 1 inch in diameter take a uniform cross-section core of soil to a depth of 6 inches just outside the area of maximum leaf drip (about one foot outside the periphery of the tree). Ten borings should be made, distributed sufficiently to represent the area under examination. If the sample is bulky, it may be mixed and a smaller composite sample placed in a manila paper bag or a pint ice cream container.

Sample B (supplementary sample from the area within the tree spread).

Obtain a composite sample by taking ten borings to a depth of six inches half way between the leaf drip (periphery of the tree) and the trunk of the tree. This sample may be taken simultaneously with Sample A, keeping the borings or cores from these two locations separately.

Comments

The results obtained on Sample A should give a good picture of the soil condition both from the standpoint of the tree as well as the cover crop, and can be used accordingly as a guide in applications of basic materials. Sample A also represents the greater part of the area in the grove having approximately the same pH value. The relative proportion and importance of the two areas depends, of course, on the diameter of the tree spread as shown in Table 2. As stated before, the soil in the area within the tree spread commonly is considerably more acid than that outside the tree spread. The pH value of Sample B will

show whether an extremely high acidity has developed in this area and whether additional basic material should be applied under the tree.

TABLE 2.—Percentage of the Total Area Within the Tree Spread in Relation to the Diameter of Tree Spread Based on Rectangular Planting 25x25 Feet.

Diameter of Tree Spread (feet)	Per Cent of the Total Area Within the Tree Spread
5	3.1
10	12.6
15	28.3
20	50.2
25	78.5

PREPARATION, DESCRIPTION, AND TRANSPORTATION OF SAMPLES

A pint portion of each sample composited as outlined above should be placed in a clean ice cream carton or tough paper bag, wrapped securely and sent to the laboratory. Each sample should carry the sample number and depth both outside and inside the container. A full description of the type of land, drainage, crops grown or to be grown, crop condition, fertilizer used, lime used, and the type and amount of cover crop should be in a letter or on a form accompanying or mailed at the same time as the samples. This phase of the procedure will be discussed a little later in detail.

It must be remembered at all times that the analysis of a soil sample is only a small part of the information necessary to solve any problem in soil fertility and that this information can at best represent the condition only to the extent that the sample represents the area from which it came.

SPECIAL SAMPLING

It is often desirable to take special samples representing soil from an area upon which abnormal plant growth exists. Such samples should be taken from the area in question within the extent of the abnormality in the same manner that other surface or subsoil samples are taken. It is recommended that duplicate samples be taken from each such area, as previously suggested for areas where greater accuracy is desirable. Samples should also be taken from the surrounding or nearby areas of normal plant growth for comparison to those of the abnormal area. The relationship of two samples to each other should be clearly indicated so that proper comparisons can be made. Samples of plant material from normal and abnormal areas are often of help in interpreting data.

ROUTINE FIELD SAMPLING AND NOTES

Alec White, Ed L. Ayers, and R. E. Norris*

(Editor's Note: In view of the fact that these discussions and those that follow, exclusive of Mr. Carrington's, were largely extemporaneous, they will be reported only briefly along the line of the main objective, namely, developing a routine for taking satisfactory soil samples for reaction determination and field notes for future reference in connection with these samples and the resampling it may be desirable to do another year, and putting these values to work.)

Mr. Alec White was in an excellent position to discuss the field phase of the problem since the compliance group of the Agricultural Adjustment Administration in Hillsborough County had already been through the experience of taking quite a large number of samples and sending them to the Experiment Station for testing prior to the time of the meeting. In this first series, separate composite samples were taken with the use of 18-inch sampling tubes in the middles and from under the trees, labeled "A" and "B", respectively, and placed in pint ice cream cartons for shipment. Identifying numbers and other pertinent data, including date of sampling, initials of sampler, and legal description of area sampled, etc., were written on the bottom of the containers rather than on the top, for obvious reasons. A red dot, indicating the general location of the area sampled in a given grove, was also placed on the official aerial map. The best estimate that could be given of the time required for this early work was from two to five per cent, on the basis of the total time required for the compliance checkup.

Mr. Ayers discussed his experience in trying to evolve a satisfactory method of soil sampling over a period of ten or twelve years and told, in brief detail, of some of the practical benefits that have been returned to growers in his county, of which he knew personally, as a result of soil tests of this nature. His discussion was in full agreement with that of Mr. White as to the practicability of having the compliance men of the A.A.A. collect the samples and field data. Mr. Ayers particularly emphasized the great variability in reaction of the soils of Manatee County ranging from a pH of 4.0 or less out on the pinelands or in acid muck pockets, to 7.5 or 8.0 for certain of the Parkwood types.

Mr. R. E. Norris presented a tentative outline for the the collection of field information that he has used with a considerable degree of success to accompany soil samples taken in Lake County. As indicated under the discussion of methods of sampling, this first outline was developed primarily for grove conditions with particular reference to the conservation program of the Agricultural Adjustment Administration. Principal emphasis is given in it to the general type of soil, variety of citrus, kind and amount of cover crop, general condition of the grove and previous liming treatment, if any. As a result of this and subsequent discussions the outline shown in Figure 3 was evolved for the collection of field information in connection with soil sampling under citrus grove conditions.

* County Agents, Hillsborough, Manatee, and Lake Counties, respectively.

Lab. No. .....
pH—"A" .....
"B" .....

FIELD SHEET FOR SOIL SAMPLING UNDER CITRUS GROVE CONDITIONS

(This grove inventory is to accompany each soil sample *or each pair of "A" and "B" samples* taken from the same grove.)

Date of Sampling .....

....
Name of Grove Owner | County Code No. | Farm Serial No.

....
Address | Sample No. | Location

Variety: Orange ( )
Grapefruit ( )
Mixed ( )
..... ( )

....
Acreage Represented

(Check the Appropriate Description)

General Grove Condition: Good ( ), Fair ( ), Poor ( ).

Bronze Leaf: Bad ( ), Medium ( ), Slight ( ), None ( ).

Frenching: Bad ( ), Medium ( ), Slight ( ), None ( ).

Kind of Cover Crop: None ( ) Clean Cultivated ( ).

Legume ( ) ....., Non-legume ( ) ....., Mixed ( ) .....
Kind | Kind | Kind

Amount of Cover Crop: Heavy ( ), Medium ( ), Light ( ).

Kind of Soil:
( ) High pine land
( ) High hammock
( ) Flat pine land, clay subsoil
( ) Flat pine land, hardpan subsoil
( ) Flat pine land, sandy subsoil
( ) Low marl hammock
( ) Low acid hammock
( ) Black-jack land
( ) Scrub land
( ) .....

Previous Lime Treatment, If Any: None ( ) Details not known ( ).

Kind of Material: ( ) Limestone, ( ) Dolomite, ( ) .....
Other

Manner of Application: ( ) Full broadcast, ( ) Middles only, ( ) Under trees only.

Rate of Application: ....
Date
....
Date
....
Date

Other Remarks:

Figure 3.

With regard to the recording and packaging of the soil samples, once they have been collected and air-dried in a protected place, the most effective container has been found to be a good strong (usually about a three pound) nail bag such as may be obtained at any hardware store. The spare top of each bag, upon which has been plainly written the requisite identifying numbers, is wrapped firmly around the sample, as shown in Figure 4, where it is also demonstrated how the "A" and "B" samples are lightly bound together by a rubber band with their field sheet. Only one field sheet is necessary for each pair of samples, since they are both taken from the same grove.

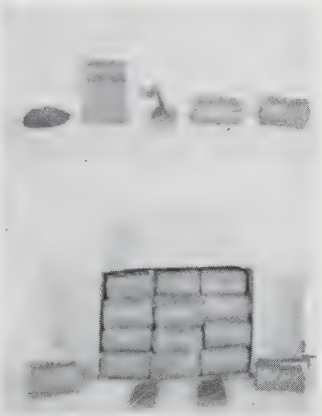

Figure 4.—Packaging soil samples, following air-drying, for shipment.

Above: The air-dry sample (about ½ to ¾ pint) is placed in a strong, 3-pound paper nail bag, or its equivalent, and the top folded down neatly and firmly against the sample after numbering legibly. The field sheet should then be folded to this size and attached to the sample with a rubber band. Where there is a "B" sample as well as an "A" sample, the single field sheet for both is lightly bound between the two samples with the rubber band.

Below: The packed carton shows how neatly and economically well packaged samples can be prepared for shipment.

A systematic listing of the samples contained in a particular lot or unit of shipment on a separate sheet will most certainly prove a convenience of great importance to the men in the laboratory. As a matter of fact, care in numbering, packaging, and listing the samples may reduce the time required to complete and report on a shipment by one half, all of which will mean a prompter return of the results to the County Agent's office and to the grower.

The type of list that should accompany each carton or group of cartons making up a particular shipment is outlined below under Figure 5. An examination of this outline, especially for the manner in which it is related to the field sheet of Figure 3, will immediately suggest the great facility it will lend to the handling of the material if it is carefully prepared.

Naturally the County Agent will want to keep a copy of the field sheet as well as the shipping list for future reference.

Code No.: 59-048
Date: August 29, 1941

Farm Serial Number	*Field Sample Number*	*Owner or Operator*
430	1 (seed bed)	L. F. Roper, Winter Garden, Fla.
430	2 (Bumby Farm) East	L. F. Roper, Winter Garden, Fla.
430	3 (Bumby Farm) West	L. F. Roper, Winter Garden, Fla.
430	4 (Vance Farm)	L. F. Roper, Winter Garden, Fla.
638	1A } Citrus Grove 1B }	W. F. Loppacher, Winter Garden, Fla.
638	2 (Plot 1, Veg. land)	W. F. Loppacher, Winter Garden, Fla.
638	3 (Plot 2, Veg. land)	W. F. Loppacher, Winter Garden, Fla.
638	4 (Plot 3, East side)	W. F. Loppacher, Winter Garden, Fla.
638	5 (Plot 3, West side)	W. F. Loppacher, Winter Garden, Fla.
638	6 (Plot 4, Veg. land)	W. F. Loppacher, Winter Garden, Fla.
9060	1A } Citrus Grove 1B }	Matzen Haugaard, Gotha, Fla.

Figure 5.--Sample packing list.

METHODS OF DETERMINATION OF SOIL pH

Richard A. Carrigan*

I. INTRODUCTION

The accuracy with which a pH test represents the area tested is dependent upon two factors: (a) the faithfulness with which the sample tested represents the soil area, and (b) the accuracy with which the test itself is conducted. Methods of obtaining representative and significant samples under Florida conditions are described in another paper of this symposium (*3*)[1]. It is the purpose of this paper to consider the commoner methods of conducting the test, to evaluate them in terms of the accuracy to be expected, and to point out certain difficulties and the means of overcoming them.

The meaning of the symbol "pH" will not be discussed here, since good explanations are available elsewhere (*1*). The interpretation of pH values in terms of soil conditions as affecting plant growth may be learned by reference to the many publications available which deal with the growth of specific crops.

Practical methods of determining pH fall into two classes known as *electrometric* and *colorimetric* procedures.

From the theoretical standpoint the electrometric method is the fundamental means of determining pH and any colorimetric method is valid only to the extent that it has at some time been calibrated against the electrometric method and found to give reliable data.

II. THE ELECTROMETRIC METHOD

ELECTRIC CELLS

In the electrometric method the sample to be tested is made a part of an electric cell or "battery." Matters are so arranged that the voltage of the resulting cell bears a definite and known relation to the pH of the sample.

Every simple electric cell is made up of three essential parts. These are the two *electrodes*, through which the electric current enters and leaves the cell, and the *electrolyte*, which is ordinarily a solution separating the electrodes. Each electrode, at its surface of contact with the electrolyte, establishes a definite electrical potential, or voltage. The individual voltages of the two electrodes combine to produce the overall voltage of the cell as a whole. The electrodes may be of metal or other solid material capable of conducting electricity, such as carbon. The electrolyte may be a solution of an acid, base or salt, or, in the case of a soil pH test, a mixture of soil and water.

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[1] Numbers in italics refer to literature citations on page 39.

A familiar example of a simple electric cell is the common flashlight "battery." In this case the electrodes are the zinc can which serves also as a container for the rest of the cell, and the carbon rod in the center of the cell. The electrolyte is the black paste soaked with a solution of ammonium chloride (sal ammoniac) which fills the space between the electrodes.

In an electrometric pH determination an electric cell is set up as follows: The solution to be tested becomes the electrolyte, or the liquid into which the two electrodes are dipped. One electrode is selected which will yield a voltage that depends alone on the pH of the electrolyte which, in this case, is the solution under test. This is referred to as the *indicator electrode.* The other electrode, known as the *reference electrode*, is chosen to be one that will set up a known voltage which is always the same, and therefore independent of the pH of the test liquid. The overall voltage of the cell, which may be determined by use of a suitable measuring instrument, is the resultant of the two electrode voltages. If the overall voltage, so measured, is corrected for the constant and known voltage of the reference electrode, it is possible to find the voltage of the pH-sensitive indicator electrode and from this to determine the pH of the solution bathing the electrodes by a simple calculation. With commercial pH meters this calculation is usually rendered unnecessary either by use of a simple numerical table supplied with the instrument or by a modification of the instrument itself whereby direct reading of pH values from a dial is made possible.

THE SOIL SUSPENSION

In running a soil pH test by this method the electrolyte is prepared by stirring up a portion of the soil to be tested with some water. The soil does not, of course, dissolve in the water in the strict sense of the word. The sand particles settle out at once but the finer (colloidal) particles are said to remain *suspended* in the water, at least until they finally do settle out (which, by the way, must not occur before the completion of the test). The resulting preparation is therefore spoken of as a *soil suspension.* Into the soil suspension are dipped the pH-sensitive indicator electrode and the constant voltage reference electrode. In this way a complete electric cell is built up which is in all essential respects a counterpart of an ordinary flashlight "battery." It has, however, the distinctive characteristic of yielding a voltage that depends only upon the pH of the soil suspension.

REFERENCE ELECTRODES

No diagrams will accompany the discussion following because of the diversity of equipment available. Any operator of a pH meter can readily identify the parts described by comparison with his own instrument or by reference to the manufacturer's literature.

The Calomel Electrode

The constant voltage reference electrode most commonly used for all types of electrometric pH determination is the one known as the saturated

"calomel electrode." The essential features of this electrode are a small quantity of mercury in contact with a small volume of a water solution which is saturated with potassium chloride and also with calomel (mercurous chloride). In commercial pH meters the entire calomel electrode unit is often made up in a compact, easily portable assembly. In using a calomel electrode, it is necessary to establish electrical connection from the mercury of the electrode to the voltage terminal of the measuring instrument. This is done by means of a metal wire leading from the mercury to the latter terminal. Contact must also be made between the saturated solution of the calomel electrode and the solution under test in such a way that the solution of the electrode cannot be contaminated by the test solution. This is accomplished by having an intervening solution of saturated potassium chloride through which the electrical current passes from the calomel electrode to the test solution. This intervening solution is accordingly known as a "salt bridge." A common commercial form of "calomel electrode" is made up integral with the salt bridge which forms an outer jacket around the calomel electrode proper. This jacket is ordinarily a glass tube filled with the saturated potassium chloride solution which communicates through a small hole with the solution of the calomel electrode in the inner tube of the unit. Connection with test solution, in which the entire unit is immersed, may be made through a minute hole in the end of the outer jacket, through the liquid film wetting the joint between a ground glass sleeve placed over the end of the outer jacket, or by other means.

Troubles with electrometric equipment are often caused by difficulties with calomel electrodes and their associated salt bridges. These disturbances are often of such a nature as not to require sending the entire pH meter back to the factory. They can frequently be avoided by careful attention on the part of the operator of the equipment and, in case of trouble not readily corrected by him, the difficulty should be satisfactorily remedied by purchasing a new calomel electrode unit. Many of these units are quite small and contain only a small quantity of liquid, so that they dry out readily. Drying out is often accompanied by a creeping of the solution over the outer surface of the electrode with the accompanying deposition of a salt-like residue of potassium chloride. If severe drying has occurred, the inner calomel electrode proper may be partially or completely empty of liquid. With a factory-sealed electrode, this condition is difficult if not impossible to correct and may mean that a new electrode must be obtained. Improved models may obviate some of this difficulty but with the "dipping" types of electrode, trouble from this source is more easily prevented than cured simply by keeping the end of the electrode immersed in water when not in use. Calomel electrodes of this type are ruined or damaged by disuse as readily as by misuse. Only by careful attention to the matter of keeping them from drying out during long periods when they are out of use can they be preserved for dependable service when they are needed.

Contact from the electrical circuit to the solution in the calomel electrode must be made *only* through the body of mercury; otherwise an unwanted source of voltage will be introduced into the system. This may occur if the solution in the electrode soaks its way through the

upper insulating cap on certain types of calomel electrode, thereby making contact directly to the wire leading from this unit. This condition is indicated if a deposit of salt-like material is seen to form where this wire emerges from the top of the electrode. In such a case, the electrode has completed its useful life and must be replaced.

In re-filling any calomel electrode, only specially purified chemicals sold for this purpose should be used unless the operator has confidence in his ability to choose a grade of suitable materials. Contamination of the electrode solution must be avoided.

The Buffer Reference Electrode

Some commercial quinhydrone pH meters make use of what is known as a buffer reference electrode instead of the usual calomel electrode. The buffer reference electrode is freshly made up by the operator himself each day the instrument is used and may consist of a simple platinum (or gold) electrode dipping in a buffer solution (see below) of known pH which has been saturated with quinhydrone. This arrangement is, in fact, an ordinary quinhydrone electrode assembly (see next section). The buffer solution in contact with the platinum electrode, however, is always of constant and known pH and the electrode may, therefore, be used as a *reference electrode* since its voltage will then be constant also. When this system is used, connection from the buffer reference electrode is often made to the soil suspension in another container by a U-shaped glass tube filled with a jelly made from the usual saturated potassium chloride bridge solution by addition of a substance known as *agar*. Another platinum electrode is dipped into the soil suspension which is saturated with quinhydrone. The latter electrode then becomes the *indicator electrode* since it behaves as a quinhydrone electrode in the solution to be tested, as will be understood from the next section. The precautions to be observed in using a buffer reference electrode of the kind described are the same as those specified for the use of a quinhydrone electrode in any other capacity.

INDICATOR ELECTRODES

The Quinhydrone Electrode

A useful indicator electrode for determining pH electrometrically is the "quinhydrone electrode." The actual electrode used with this system is a piece of platinum or gold, but, in order for it to register a voltage which is related to the pH, the test solution (or soil suspension) is saturated with a substance known as quinhydrone, before taking a reading. Thus, a platinum electrode in contact with a solution saturated with quinhydrone is called a "quinhydrone electrode." As with any electrometric method, it is necessary to establish two electrical connections to the test solution. One of these is made through the pH-sensitive platinum electrode; the other is made, as usual, through a constant voltage reference electrode. The latter is ordinarily a calomel electrode or the buffer reference electrode described in the preceding section.

Advantages of the quinhydrone electrode are (a) that electrical measuring equipment of moderate cost can be used and (b) that subtle

sources of error due to failure of electrical insulation are not likely to cause trouble as with the more elaborate glass electrode instruments. Disadvantages are (a) that the quinhydrone electrode is not applicable at pH values above about 8.5, and (b) that with some soils it is impossible to get stable readings due to an uncontrollable drift in pH caused by the presence of the quinhydrone itself. The first of these disadvantages is not serious with most Florida soils. Limited experience indicates that the second disadvantage may operate with only relatively few of the soils of the state, but more data are needed on this point. The "quinhydrone drift" is recognized by the inability to get a reading that remains the same long enough for its value to be determined satisfactorily. When this happens, the closest approach to the correct value will probably be obtained by taking a reading as quickly as possible after adding quinhydrone. In any case, the reading will be uncertain if a drift occurs.

In using the quinhydrone electrode with soils, however, two precautions are outstanding. (a) Sufficient quinhydrone must be added and it must then be brought into very thorough contact with the soil suspension by vigorous agitation so as to saturate the suspension thoroughly. Quinhydrone is not very readily wet by a water solution. It tends to "ball up" and float on the surface. This tendency must be overcome with each sample and may be done conveniently by confining the mixture of soil suspension and quinhydrone in a corked vial and shaking violently or by whipping the quinhydrone down into the solution by vigorous stirring in an open container. Failure to get good admixture of quinhydrone has led to drifting readings which have been mistaken for the typical "quinhydrone drift" already mentioned, but in cases when no drift would have occurred if proper mixing had been achieved. (b) The platinum or gold electrode must be more than just superficially clean. It is not necessary that the platinum surface be bright, but it must be free from obscure surface contamination. Treatments commonly recommended are soaking in warm half and half nitric acid or in warm chromic acid cleaning solution (the familiar red cleaning solution of chemical laboratories).

When neither of these treatments suffices to put the electrode into condition to give accurate results, the procedure of Coons is likely to be of great help. (*2*). This involves placing the electrode in a water solution of sodium bisulfite (5-10%), bringing to a boil, continuing to boil for about five minutes, and allowing to cool without removing from the solution. After this the electrode is washed in distilled water. If the electrode assembly contains mercury, this should be removed before the treatment and replaced afterwards.

Neither a quinhydrone nor any other electrode should be used until it has been determined to be giving accurate results. To check on the performance of an electrode, the pH of one or more "buffer solutions" of accurately known pH should be measured with the electrode. It is important that this be done every day the instrument is used. A buffer solution is a solution which tends to maintain its pH accurately despite the action of influences (such as contamination, aging, dilution, etc.) which act to change it. Standard buffer solutions of accurately known pH can be purchased from the dealers in pH equipment for checking

performance of pH meters. Although a buffer solution tends to maintain a constant pH, it can deteriorate if not preserved carefully. A solution should be regarded with suspicion if it shows evidence of contamination or invasion by microorganisms. After a portion of buffer solution has been used to check a quinhydrone electrode, it must be discarded, since the quinhydrone soon oxidizes and renders the solution unfit for use.

The Glass Electrode

The glass electrode is tending to supplant the quinhydrone electrode in soils work due to the aforementioned characteristic of the latter electrode of giving drifting and erroneous readings with occasional soils. The glass electrode is another pH-sensitive "indicator" electrode, which, when properly used, will give correct readings even with soils that would give drifting readings with a quinhydrone electrode. In using a glass electrode, no quinhydrone is added to the sample. The glass electrode is not limited to pH values under 8.5 as is the quinhydrone electrode. As with the quinhydrone system, the glass electrode is ordinarily used in conjunction with a calomel reference electrode.

It is now generally believed that the glass electrode is capable of giving correct pH readings with all soils and its use is now widely accepted as being the best practice in soil pH work. Before it could be put to practical use however, it was necessary to develop devices suitable for measuring the voltages generated by it. Ordinarily we think of glass as being a non-conductor of electricity, so it seems at first sight that it would be impossible to construct an electrode from it. As a matter of fact, no solid substance is a perfect insulator. Even glass will permit the passage of minute currents of electricity. The currents that do flow through a glass electrode are, however, exceedingly small, so small, in fact, that ordinary electrical measuring instruments are not able to register them. Thus, the electrical measuring equipment ordinarily used with a quinhydrone electrode would be inoperative with a glass electrode. In order to make the electrical circuit sensitive enough, some means of amplifying the minute electrical current must be employed. This is accomplished by means of one or more vacuum tubes ("radio" tubes) acting in the measuring circuit. In this way it is possible to get a current large enough to actuate the indicating needle of the galvanometer or milliammeter from which readings are taken. The necessary vacuum tubes are incorporated in all of the commercial sets offered for sale for use in determining pH with the glass electrode.

Electrical Leakage Troubles with the Glass Electrode

Although certain difficulties inherent in the quinhydrone electrode are obviated by use of the glass electrode, the extreme sensitivity required for this type of test often leads to trouble of another sort. This arises from the fact that when measurements are made upon any system having such high electrical resistance as the glass electrode, the electrical insulation employed in certain parts of the apparatus must be unusually good. In an electrical measuring circuit, minute currents may flow over the surfaces of the various insulators. When a system such as a glass

electrode and accompanying calomel electrode is being measured, where the current that must be detected is exceedingly small, it is possible for these surface currents to be of a magnitude comparable with the current through the glass electrode itself. The unwanted leakage currents, as they are called (since they are in the nature of leakage of electricity over the insulators), often get into the measuring system of the pH meter and cause fictitious results to be obtained. Thus, if in addition to the current through the glass electrode, there is also another current affecting the readings, the latter current will cause incorrect values to be registered. In running glass electrode pH measurements, it is necessary to know where these electrical leakages are likely to occur, at least if irksome difficulties with attendant delays are to be avoided. Those parts of the instrument at which leakage may be expected to occur are: (a) across any insulator which serves the function of supporting the wires leading from the glass and calomel electrodes to the measuring instrument proper (some exceptions, depending on the type of circuit employed), (b) over the *outside* of the glass electrode, in a path leading from the terminal at the top of this unit down to the solution under test, (c) over the supporting members which hold the glass and calomel electrodes in place during the reading, (d) over the support which holds the sample cup, or beaker, in place during measurements, and (e) over the outside of the glass envelope of the vacuum tube ("radio" tube) which is connected to the wire leading from the glass or calomel electrode. Any well-designed glass electrode pH meter will be provided with good insulation at all of these points; but the leakage is most likely to occur over the *surface* of an insulator and not through its body. Surface leakage of this kind is ordinarily the result of some form of contamination of the surface. This may result from the presence of an imperceptible film of moisture which may deposit at times of high atmospheric humidity, or it may be caused by accumulations of dust, laboratory fumes, or other foreign material. With these facts in mind, it is possible to avoid much of the trouble commonly encountered in glass electrode work. A proper appreciation of the degree of cleanliness required is not always obtained by reading the instructions supplied by the manufacturer of the instrument. It is perhaps no more than a slight exaggeration to say that the operator of glass electrode equipment should be as careful of the condition of the insulators of his set as a surgeon is of the sterility of his instruments. To this end, the pH meter should not be stored in a laboratory where fumes are frequent; dust must not be allowed to gather on the insulators; solutions must not be spilled on them, and they must be kept absolutely free of the ever-present potassium chloride (the white salt-like material in the calomel electrode). It is preferable not to touch an insulator with bare fingers any more than is absolutely necessary. In short, the strictest cleanliness must be observed in connection with all parts of the instrument, especially those external parts associated with the electrodes.

Regarding errors due to electrical leakage, an important consideration must be kept clearly in mind. This is the fact that errors due to this cause are not constant but vary in a way that depends on atmospheric humidity, the extent and kind of contamination and, what is most important, on the pH of the solution being tested. These facts lead to the

important conclusion that it is not possible to allow for leakage errors by establishing a constant correction to be applied alike to all determinations run on the day the correction is determined. To place faith in a "correction factor" determined by running a standard buffer solution of known pH is to invite hidden errors which must necessarily be overlooked in the very nature of the case. The instrument is either functioning properly or it is not. The only uniformly safe procedure is to check the performance of the meter every day it is used. If it is not giving the required accuracy for the purpose at hand, steps should be taken to remove the cause of the trouble and not to "correct" all readings on the basis of the readings taken on the standard buffer solutions.

Checking the Performance of a Glass Electrode pH Meter

With these facts in mind, it is appropriate to consider what steps need to be taken in order to determine beyond a reasonable doubt whether a glass electrode pH meter is working properly before proceeding to take readings. If the batteries in the meter have run down, if a switch has failed, if there is a loose connection in the circuit, or if a vacuum tube has "gone dead," in all probability the difficulty will be immediately recognized by the obvious failure of the instrument to respond in the expected manner to the manipulations specified in the instructions. Troubles of this nature are therefore not likely to pass unnoticed. With leakage errors, however, the case is different. With certain types of equipment, it is entirely possible for the operator to follow all instructions of the manufacturer, and yet be unaware of hidden errors due to this cause. No one assumes that a clock will keep correct time simply because it runs on being wound. There is no more reason to assume that a pH meter is giving trouble-free service merely because it responds as expected to the adjusting operations preliminary to taking the actual pH readings. Just as the owner of a clock checks its performance against standard time signals, so the pH operator may determine whether his instrument is giving correct values by equally simple means. The test is made by using the meter to measure the pH of *two* buffer solutions of accurately known pH. These buffer solutions should have pH values lying near the pH range of the samples to be run; they must also differ in pH from one another, preferably by about three pH units. Suitable buffers for soils work may have pH values of 4.0 and 7.0 (or 8.0). If the instrument is functioning properly, correct readings will be obtained on *both* buffers.

The recommendation just given for checking the performance of a glass electrode pH meter differs in an important respect from instructions often given for this purpose. Some instrument manufacturers commonly supply a *single* buffer solution with each instrument sold, specifying that before running tests on each day the instrument is to be used, it should be checked against this buffer. If the correct reading is not obtained, an adjustment is made on the instrument by means of convenient manipulation of a "zero adjustor" which is intended to provide correction to allow for the asymmetry potential of the glass electrode. This step can do no more than correct for the asymmetry potential. (The asymmetry potential is an extraneous voltage inherent in each individual glass

electrode; it varies only very slowly and may therefore be legitimately corrected for by this procedure.) Since this adjustment against a single buffer merely corrects for the asymmetry potential, it cannot be expected to reveal at the same time whether the instrument is performing as it should. In order to determine this, it is now necessary to test the instrument by measuring the pH of *another* buffer of different pH, having used the first buffer solely for establishing the necessary correction. If a leakage error exists, the test with the second buffer will reveal it. If the second buffer were not used, however, leakage errors of serious magnitude might pass unnoticed; the instrument might then give correct readings only at the pH of the first buffer, since it was *made* to do so by the procedure of "zero adjustment." If the meter is working in good order, the reading with the second buffer will accord with the known pH of that solution.

Too much emphasis cannot be placed on the necessity of frequent checking against two buffers, as outlined in the preceding paragraphs. It is well to do this before and after running samples every day the instrument is in use, especially if it is not used regularly.

Before leaving the subject of electrical test instruments, it is well to call attention to the necessity of keeping all electrical contacts in good condition. Workers without special training in the use of electrical equipment are prone to overlook this important detail. Whenever the instrument behaves in an erratic manner or when its indications are affected by slight vibration, a poor contact should be looked for. All permanent connections within the body of the meter are soldered. Certain connections, however, must occasionally be manipulated by the operator of the instrument. Such are the battery connections and the points of contact between the glass and calomel electrode lead wires and the measuring instrument itself. Metal contacts at all these points must be kept clean and bright where metal touches metal and, by all means, screwed contacts must be made *tight*. Failure to observe these precautions is a common source of easily remedied trouble.

A pH meter should at all times be kept in a dry place.

Preparation of the Soil Suspension and Conduct of the Test

The preparation of the soil suspension for an electrometric pH determination is a relatively simple matter. There are certain precautions, though, that should be kept in mind.

It is desirable for soil samples to be dried by exposure to the air at ordinary temperatures as soon as possible after sampling, particularly so with samples containing much organic matter, lest the activities of microorganism alter the pH before the test is run. Too small a sample of the air-dry soil should not be taken for preparing the soil suspension: otherwise the portion selected is likely not to represent the average composition of the whole sample brought in from the field. Some pH meters require only about a thimble full of soil suspension for a test. With such equipment it is desirable to prepare a larger quantity of soil suspension than actually needed in order that a reasonably large portion of soil will be used for the test.

The procedure in use in the Department of Soils of the Florida Agricultural Experiment Station will be described. The conditions chosen are the result of an effort to use the least possible quantity of water for a given amount of soil compatible with the nature of the equipment in use. A 50 cc. beaker of air-dry soil, which has previously been mixed and screened through a sieve (having holes of diameter 2 mm.) is measured into a 150 cc. beaker and 100 cc. of distilled water added. The water and soil are stirred well with a heavy glass rod and the suspension allowed to stand for from one to two hours. At the end of this time the suspension is vigorously stirred again and the glass and calomel electrodes immersed in it at once and a reading taken. With peat and muck soils 10 parts of water are taken to one of soil (by weight) and allowed to soak three hours. The extra time of soaking is intended to allow for the tendency of these soils to resist wetting after they are once dried out.

Even if the smaller type of sample cup on certain pH meters is used, it would be better to prepare the soil suspension on a larger scale, as just described. Then, after soaking an hour or two, the soil suspension may be stirred and a small portion of the turbid suspension transferred to the sample cup for the reading. In doing this, one precaution must be observed. It does no harm for the coarse sand particles to settle out and be left in the original container, but the finer colloidal material (clay particles and very finely divided organic matter) must not have settled appreciably before the transfer is made. The colloidal material must remain in suspension since these fine particles must actually be in contact with the glass (or quinhydrone) electrode at the moment the reading is taken. This is why, in any case, the suspension is always stirred immediately preceding the taking of the readings.

As pointed out earlier, potassium chloride from the "salt bridge" associated with the calomel electrode must not contaminate the soil suspension before the reading is taken. Such contamination leads to low results with acid soils.

If the individual worker prefers to use samples in the field-moist condition, he should recognize the difficulty of getting adequate mixing of soils while damp. This may, of course, be possible when suitable precautions are taken to insure that a representative sample is used in the test.

Care should be taken to see that portions of powdery marl samples do not remain on the sieve in a cake-like deposit to contaminate later samples of poorly buffered sandy soils and so affect their pH values seriously.

III. THE COLORIMETRIC METHOD

Colorimetric methods find favor where the expense of electrometric equipment cannot be justified because of the small number of samples to be run. The colorimetric technique has the advantage that it requires only inexpensive and simple apparatus which is light in weight and which occupies but little space. Moreover, the procedure is quite simple. Disadvantages are (a) that the readings taken depend on the personal judgment of the observer, (b) that the procedure used is not

susceptible of the degree of precision attainable with electrometric methods, and (c) that in some colorimetric procedures inconveniently small samples are necessary.

In the colorimetric method, pH-sensitive dyes are used which alter their colors on being brought in contact with the material tested in such a way that the resulting color of the dye is dependent on the pH of the sample. Such dyes are known as *indicators*. The pH of the sample is determined by matching the color assumed by the dye against a series of color standards, each color standard corresponding to a definite pH value.

Several portable kits for carrying out colorimetric pH tests on soil are available commercially. In order to determine the accuracy obtainable with one of these kits, a series of 155 samples of soil from the sandy citrus areas of Florida were subjected to the colorimetric test. Glass electrode pH determinations had been run on the samples and are considered to give the correct values, against which the colorimetric values may be compared to determine their accuracy. Each sample was tested colorimetrically by three different operators, all of whom worked independently of one another and were in ignorance of the correct values as obtained on the glass electrode. No effort was made to train the operators to check one another. Each operator was allowed to develop his own judgment, subject only to a reasonable amount of training.

The colorimetric method selected for study was that provided in the LaMotte-Morgan Soil Testing Set. This equipment, together with fresh indicator solutions and new color charts, was obtained from the LaMotte Chemical Products Company, Baltimore, Maryland. The LaMotte-Morgan procedure calls for allowing several drops of the indicator solution to percolate through a small quantity of soil retained in a depression on the slanting side of a special porcelain block. After passing through the soil, the indicator solution passes down a shallow trough to another depression lower down on the block, where the color of the indicator is compared with a standard color chart.

The results of the comparative study are presented in the accompanying table. Before tabulating, all errors were rounded off to the nearest 0.1 pH unit. The three operators are designated as Observers "A", "B", and "C". The table shows what percentage of each observer's readings fell within a given range of error. Thus, reference to the table reveals that 62 per cent of the tests by Observer "A" were within 0.1 pH of the truth; 92 per cent of this observer's tests were within 0.3 pH of the correct value; or, to state it differently, 8 per cent of his values were at least 0.4 pH in error. The data of Observer "C" were somewhat less accurate. The latter observer obtained values within 0.1 pH unit of the correct value in only 23 per cent of his tests. Seventy-six per cent of his values were within 0.3 pH of the truth, so that 24 per cent of his tests were at least 0.4 pH off, either too high or too low. Judged on this basis, Observer "B" attained an accuracy intermediate between that of the other two observers, except for the fact that he registered a few more very large errors than the other two.

Comparison of LaMotte-Morgan Colorimetric Determinations with Glass Electrode Data.

The figures in all but the last two columns show what per cent of an observer's readings agreed with the glass electrode values within the limit of error shown at the head of each column. The last two columns show what per cent of each observer's readings were too low and too high respectively.

Error, pH Units	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	Per Cent Low Readings	Per Cent High Readings
Observer A	29	62	81	92	99	99	99	99	100	57	14
Observer B	10	34	59	76	87	91	93	95	98	35	55
Observer C	5	23	50	76	88	96	99	99	100	92	3

Further interesting comparisons between the three observers are shown in the last two columns of the table, in which are given for each observer his percentage of low results and of high results, respectively. Thus it is seen that Observer "A" obtained values which were too low by at least 0.1 pH unit in 57 per cent of his readings, while only 14 per cent of his readings were too high. Observer "C" had an even more pronounced tendency toward low results. Observer "B", on the other hand, showed only a moderate trend toward high results. In other words, any single determination by Observer "B" is almost as likely to be too low as to be too high. When it is considered that Observer "B" reported values which were at least 0.4 pH unit in error for 24 per cent of his tests, it is obvious that the interpretation of his data under actual routine conditions would be rendered somewhat uncertain. About one out of each four of his tests would be at least 0.4 pH unit from the true value and there would be no way of knowing whether the reported value were too high or too low in a given case. Thus, for any given reported reading, the true value for the sample might lie anywhere within a range of pH so wide that a recommendation based on the reading might be significantly in error.

The preceding conclusion applies, of course, to Observer "B". The other two observers reported data of considerably more value in that Observer "A" attained a higher degree of accuracy, and both Observers "A" and "C" were more consistent. That is to say that the errors of the latter two observers were usually in the same direction, so that there would be less uncertainty regarding the range within which the true pH value corresponding to a given reading might lie, as contrasted with the tendency of Observer "B" to obtain readings which were about as likely to be high as to be low.

Before attempting to arrive at an interpretation of the data presented in the table, it is first necessary to have some criterion for deciding what would constitute satisfactory performance for the colorimetric method in terms of its ability to reproduce results obtained by the glass electrode. It is sometimes argued that comparatively rough determinations are

adequate, on the basis that the sampling error is relatively great and that there is no need for the test to be more accurate than the sampling procedure. To a certain extent, this reasoning in logical. If the field sample in any given case represented the area sampled with an accuracy of no more than two or three tenths of a pH unit, then there would be no need of insisting on having a test method which could yield readings accurate to within two or three hundredths of a pH unit. On the other hand. if the test itself is subject to errors as great as, or greater than those of the sampling procedure in the case cited, then there is danger that in a considerable number of tests the error of sampling will combine with the error of the test method to produce an overall error too great for safety. The truth of this statement is especially evident when it is remembered that for any given test it will not be known whether the value obtained is too high or too low. In order for a pH test method to be considered *completely* satisfactory, it would not seem unreasonable, therefore, to require that it should be capable of yielding readings which are in no case more than 0.2 pH unit from the true value for the small portion of soil actually tested. The choice of 0.2 pH for this limit is, of course, quite arbitrary, since the accuracy needed is dependent to some extent on the use to which the test is to be put. It should not be concluded that any test of somewhat lesser accuracy should be discarded, since the question of expense is sure to be a determining factor where only a small number of samples are to be run. In cases where only the less expensive colorimetric methods can be afforded, more samples should be run from each area in order to achieve at least a partial compensation for the lower accuracy obtainable on a single sample. Larger organizations and testing agencies would do well, however, to make use of the more reliable electrical methods.

Consideration of the data in the table shows that the particular colorimetric method studied is at best but a substitute for the glass electrode, although it will find, however, a certain field of usefulness. It is at once evident that different operators will use the method with varying degrees of success. For reasons already explained, Observer "B" reported readings which were quite unsatisfactory. The data of Observer "C" were not particularly satisfactory. An operator with the skill of Observer "A" could, however, obtain useful data, even though there would be much to be desired from the standpoint of accuracy. Thus 81 per cent of this observer's readings were within 0.2 pH unit of the correct value or, stated differently, about one reading out of every five was outside of the limit of accuracy which we have tentatively established. No operator should, however, take it for granted that he will be able to equal the performance of Observer "A". Experience with other users of the test who have sent samples to the laboratory for checking their colorimetric results against glass electrode determinations has indicated that Observer "A" may have been exceptionally skilled in using the test. Moreover, the data reported here were obtained under favorable laboratory conditions and cannot be taken to represent what might be expected in the field where workers, no matter how conscientious, would be under certain disadvantages. These disadvantages are: (a) limited supply of distilled water for washing apparatus, (b) difficulty of pro-

tecting color charts and indicator solutions from premature fading and contamination and (c) the serious difficulty of obtaining samples in an air-dry condition so that they may be put through the thorough process of mixing necessary to insure that the small portion of soil used in a color test will be representative of the entire sample withdrawn from the field. The conclusion to be drawn from the evidence submitted would seem to be that before any worker undertake to use the colorimetric method he should determine what accuracy he is capable of attaining by comparing a large number (at least twenty-five) of his test results with glass electrode determinations on a variety of soils. He would thus know whether he has the inherent ability to make the necessary color evaluations with the precision required for attaining accuracy comparable with that obtained by Observer "A". Experience is doubtless of some help in this connection. Conditions peculiar to the individual operator's work, such as suitability of water supply, would also be evaluated by such a comparison, so that if anything were wrong it would be easily possible for him to recognize the difficulties and limitations of his procedure. A procedure that has been found particularly desirable in cases where workers must use colorimetric methods is to have periodic check-ups by comparing data with the glass electrode on at least a dozen samples about every three months. Only in this way can each operator maintain a constant check on the accuracy he is attaining.

The conclusions arrived at in the preceding are derived entirely from experimental work on the LaMotte-Morgan method. The soils used came entirely from citrus areas. Experience indicates, however, that the recommendation given above can well be applied to colorimetric methods in general.

Regarding the use of colorimetric methods, a few precautions are worth mentioning. Filtration of soil-water suspensions through filter paper preparatory to determining pH on the water extract as a means of arriving at the pH of the soil is a procedure that can lead to errors approaching as much as an entire pH unit.

With any colorimetric method it is necessary to have a clear understanding of the fact that any indicator is capable of giving indications of pH only with a sample the pH of which falls within the pH range over which the indicator in question changes color. Thus, if phenol red is being used, it must be realized that this indicator gives a yellow color at pH about 6.6 and also at all pH values below this point. In other words, the color of this indicator reaches almost its maximum degree of yellowness at this pH and its color will not change much more on going below pH 6.6. Accordingly, if a reading of about pH 6.6 is obtained with this indicator, the operator must not fail to check the determination by use of another indicator, the pH range of which overlaps the range of phenol red on the low pH side of the latter indicator, for example bromthymol blue which covers the range 6.0 to 7.6. Failure to check with another indicator in such a circumstance is almost sure to lead to occasional, and probably frequent, errors of extreme magnitude. As a matter of fact, whenever possible, each sample should be checked with two different indicators. Such a procedure will, in fact, do much

toward making the operator realize the limitations of the procedure he is using.

Great care needs to be taken to preserve color charts and indicator solutions in good condition. Color charts should not be exposed to light more than necessary and must not be allowed to become wet or soiled. New charts should be provided when old ones lose their original appearance. Indicator solutions and charts must be supplied by the same manufacturer for use with each other.

Color comparisons are best made in daylight. A bench indoors, facing a north window, is excellent.

Apparatus must be cleaned carefully between each determination, with final rinsing with distilled water. Traces of soap and other cleaning materials which might affect readings must not be allowed to remain in the apparatus.

In comparing colorimetric readings with electrometric data, the operator should always make his colorimetric readings before referring to the electrometric values. Otherwise the most conscientious worker will probably be under the almost unavoidable psychological disadvantage of being unable to exercise his judgment of color independently of his prior knowledge of the correct result.

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METHOD OF REPORTING RESULTS TO THE COUNTY AGENT AND TO THE GROWER

E. F. DeBusk* and L. H. Rogers*

Once the soil samples have been taken and the reaction values determined, it was not deemed advisable by Messrs. DeBusk and Rogers to undertake to make detailed recommendations from the Experiment Station especially in view of the large number of samples that may be involved and the extremely limited amount of help that is available to take care of this type of work. Accordingly, it was decided that a form should be developed to report these values back to the County Agent for distribution to the grower with any comments or recommendations that the Agent may care to include on the basis of his personal knowledge of the property, over and above the information shown on the field sheet.

Farm Serial No.[1]	Field Sample No.[1]	pH	Laboratory Number
1547	A	5.68	394
1547	B	5.47	395
1572	1A	6 12	364
1572	1B	5.75	365
1572	2A	5 58	358
1572	2B	5.49	359
1573	A	6.05	374
1573	B	5.93	375
1576	A	5.81	372
1576	B	5.31	375
1579	A	5.78	333
1579	B	5.59	334
1591	A	5.30	321
1591	B	5.77	322
1616	A	5.61	352
1616	B	4.77	353
1648	1A	5 68	688
1648	1B	5.78	389
1648	2A	6 09	335
1648	2B	5.98	336
1648	3A	5.73	237
1648	3B	5.10	238
1665	A	5 10	323
1666	B	6.16	324

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Figure 6.—Form for reporting reaction values to the county.

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[1] See also Figure 3.

Inasmuch as the County Agent will doubtless keep a copy of the field sheets in his office, it was thought sufficient for these report forms simply to list the reaction values according to the consecutive laboratory numbers given them when they arrive at the Experiment Station along with their county serial number, and their subordinate field numbers, which will serve to identify them in the records of the County Agent's office as to farm, field or grove, and operator. The laboratory number serves for ready reference to the samples of each county for whatever period they are held in storage. These numbers are also useful in affording a ready record of the number of samples that have been sent in from a particular county and in otherwise facilitating their handling. Such a tabulation form as might prove useful in sending the reaction information out to the county offices is to be found in Figure 6, where a typical set of values are presented exactly as they were reported back to the County Agent.

On the basis of these values the County Agent is in a position to arrange them on cards for each individual field or area sampled in such a way as to bring together the reaction values of each for a succession of seasons. Such a card should also provide a place for date, rate, and manner of soil treatment with liming materials. The advantage of such a record is obvious in following the effect of the treatments that are being made from season to season. Such a study is in line, furthermore, with the keynote of conservatism in the application of liming materials that was sounded above, especially in the avoidance of too heavy treatments or overliming.

DISCUSSION

H. G. Clayton, *Leader*
W. E. Stokes
A. F. Camp
R. P. Thornton

Mr. H. G. Clayton opened the discussion by very briefly outlining the prospective liming program of the Agricultural Adjustment Administration in the State. He not only touched on the financial manner in which it would operate but also emphasized the real need for carefully determined reaction values on soil samples that had been taken with equal care as a basis for liming recommendations. He then called on Messrs. Thornton, Stokes, and Camp to assist in leading the discussion. Doctor Camp was out of the room for a time but returned to take part in the three-quarter-hour of discussion that followed.

In his brief discussion of the subject, Prof. Stokes emphasized the need for recognizing other factors than soil reaction as well as the limited amount of information available on the lime requirements of agronomic crops. He expressed himself as strongly in favor of bringing all available data and opinion, based on experience, to bear on the question from every angle and urged this phase of the problem upon the attention of the group. The strong plea for conservatism in the use of reaction values as a basis for determining the amount of lime to apply was well supported by the comments from the floor that followed, which left little doubt, however, that carefully determined reaction values could and should be of much greater value than personal opinion.

Mr. R. P. Thornton briefly reviewed his several years of experience in the sampling and analysis of soils and supported in quite a definite manner the need for a well established routine for taking, labeling, and preparing soil samples for shipment to the laboratory as a basis for the work to follow. He also commented on the discussion of methods by Mr. Carrigan and recommended the use of the glass electrode for reaction (pH) determinations wherever it was at all feasible to do so.

The extensive soil reaction survey developed in South Carolina a few years ago by Dr. H. P. Cooper, now Director of the State Experiment Station at Clemson, was brought to the attention of the group by Prof. E. L. Lord. He quoted the survey, which involved many hundreds of thousands of samples of soil—one from each field of each farm of the state, in fact—as showing forty per cent to be more acid than pH 5.5. Mr. Lord declared a similar condition prevailed in practically all virgin soils in Florida. Such a reaction he regards as definitely unsatisfactory, calling attention, at the same time, to the difficulty of maintaining an adequate supply of lime in the soil against normal leaching losses. In connection with the above survey Mr. Gray Singleton of the Federal Land Bank, Columbia, South Carolina, pointed out that prior to Dean

Cooper's soil reaction survey in South Carolina the average rate of application of lime was 214 pounds per acre. Following the work it rose to 368 pounds per acre. Mr. H. G. Clayton called attention to the fact that the Agricultural Adjustment Administration of South Carolina has a liming program under way in that State at the present time.

The value of a reasonably accurate knowledge of soil reaction (pH) in strawberry culture was well brought out by Dr. A. N. Brooks, in charge of the Strawberry Laboratory at Plant City. As the result of several years of work with the soils of Eastern Hillsborough County, he has found that a pH of 5.5 is about optimum for this crop. The very definite dangers of overliming were also referred to briefly and reference made to the need for manganese and for the use of acidic fertilizers or other acidulating materials under such circumstances.

Mr. Robert Edsall, of Wabasso, raised a question regarding the effect of the moisture content of the soil at the time of sampling on the reaction value that it shows with the comment that he has observed an undried field sample reading as high as pH 7.5 drop as low as pH 6.8 upon being tested after air drying. On the other hand, he has observed soils showing a pH as low as 5.2 in their undried state to increase in this value upon being dried. In response to this inquiry, Dr. Peech said he had not found appreciable variation in reaction as the result of air drying light sandy soils. Edsall commented that only soils with high replaceable calcium show this effect. The question was then raised whether, for instance, a soil should be limed that showed a pH of 6.0 when moist and of 5.6 when air dried. The principal comment on this inquiry was to the effect that working at field moisture content does not give a permanent point of reference. Neither does air drying bring about a permanent change in the soil. In other words, the reaction (pH) of most soils must fluctuate considerably in the field under normal conditions. An instance was made of the immediate rise in the pH of the soil after adding organic fertilizers. Mr. Edsall then asked whether it might be possible to develop a factor for converting reaction values from one basis (air dry samples) to the other (undried samples).

In response to the above question, Dr. A. F. Camp referred to an experience he had several years ago with a soil sample from a blueberry area. The sample was brought to the laboratory in a tightly closed container. The reaction was found to rise a full pH (from 4.5 to 5.5) in a couple of days. Furthermore, no stable e.m.f. could be obtained with the hydrogen electrode until all ammonia was removed by aeration. Such experiences are not uncommon and suggest the advisability of air drying the samples in an airy, well-protected place as soon after taking as possible.

Mr. A. M. Hill, Jr., of Vero Beach, asked on what basis liming recommendations should be made after determining the pH value of the soil, stating that the National Lime Association has a simple procedure for determining lime requirement. Dr. Camp stated that lime requirement depends on the texture of the soil as well as its pH and noted that while this value can be determined from a knowledge of the reaction and exchange capacity, the maintenance of a given reaction in the soil is made difficult in practice because of variations in the spray program

(under citrus grove conditions). Inasmuch as dolomite has been found slower in its action and less likely to result in overliming effects, it was referred to as a conservative material to use where there is any question.

In response to a further question raised regarding the danger of applying too much lime to sandy soils of low pH, Dr. Peech referred to certain experiments in progress and expressed the opinion that fairly accurate recommendations can be made if the reaction of the soil and the records of the fertilizer and spray programs are available for a given area.

On the whole, it appeared that the most urgent need is the development and adoption of a standard procedure and close adherence to it so that plant performance in the field can be calibrated against it. In other words, if we undertake to check variable plant responses against variable results derived from using different methods, it will take a long time to get anywhere.

Earlier in the discussion, Mr. H. G. Clayton called attention to the fact that the Agricultural Adjustment Administration has the organization and routine machinery available for carrying out a liming program if the need for lime can be determined. He also asked for a motion to appoint a committee to develop a method of procedure for getting soil reaction determinations made on a sufficiently comprehensive scale to be of practical assistance. This motion was made and seconded at the close of the general discussion and carried. Mr. Clayton then commented very cordially on the excellence of the attendance and of the interest displayed in the program throughout the afternoon and turned the meeting back to the general chairman with the request that the committee on the soil testing program be appointed in the course of the Business Meeting to follow.

BUSINESS MEETING

R. V. Allison, presiding

The first item of business was the appointment of a committee to develop the details of the soil testing program. After a considerable amount of discussion, the chair was invested with requisite authority and appointed all County Agents present to act as a sub-committee of the Committee on Methods of the Soil Science Society of Florida. A meeting of this sub-committee was requested for 7:30 P.M.

The purpose of the various subject matter committees of the Society, as provided by Article IV of the Constitution, were briefly reviewed and the question of setting up an Extension Committee as well as one on teaching was advanced for discussion and very favorably received. Mr. Colin D. Gunn, State Coordinator of the Soil Conservation Service, asked whether it would not be a good idea to have representatives from various civic and other organizations on the Extension Committee, as well as members of the Extension Service. As to the Teaching Committee, it was suggested that this group might well include vocational agriculture teachers, a representative from the Board of Education, etc. Both suggestions were favorably received.

The name of the proposed chairman and membership of those committees that had been developed to date were presented and tentatively approved with the understanding that final approval of the general setup would be at the time of the Second Annual Meeting of the Society in Gainesville late in May. Following is the complete list of committees, together with their chairmen:

I.	Membership	Secretary Executive Committee
II.	Soil Survey	Ernest R. Graham
III.	Methods of Analysis	L. H. Rogers
IV.	Research	L. W. Gaddum
V.	Terminology	G. M. Volk
VI.	Soil and Water Conservation	Geo. B. Hills
VII.	Fertilizer Recommendations	W. L. Tait
VIII.	Teaching	F. B. Smith
IX.	Extension	Ed L. Ayers
X.	Tropical Soils	H. H. Bennett
XI.	Forest Relationships	H. S. Newins
XII.	Animal Relationships	R. B. Becker
XIII.	Human Relationships	Chester F. Ahmann, M.D.
XIV.	Resolutions and Press	W. F. Therkildson

A lively discussion developed on the need for an expansion of our studies in the field of soil microbiology, which included the suggestion that they be extended to the investigation of the trace element needs of the microflora of the soil as well as those in such specialized environment as the compost heap. Mr. R. P. Thornton recommended a committee or individual to search abstracts of articles dealing with important phases of Soil Microbiology of interest to the members of the Society.

The Second Annual Meeting of the Society was proposed for Gainesville on May 29 and 30 in conjunction with the regular Annual Convention of the Florida State Florists Association and favorably acted upon. It was also announced that Dr. Selman A. Waksman, internationally known Soil Microbiologist of Rutgers University in New Jersey, would be a guest of honor at the Gainesville meeting and deliver a principal lecture on "Microbes in a changing world"; also give a more practical talk on "Peat and its uses" on one of the regular programs of the meeting.

The meeting adjourned at 5:50 P.M.

ANNUAL MEETING

Gainesville, Florida, May 29-30, 1940
Joint Meeting with Florida State Florists' Association

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May 29, 1:30 P. M. - 5:00 P. M.

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NOTES ON THE SOIL CLINIC

G. M. Volk* and R. A. Carrigan*

A soil clinic was conducted for the purpose of demonstrating what could be done in the way of ascertaining soil nutrient deficiencies by soil analysis. It was hoped that a demonstration of the technique of analysis and a summary of the data obtained would help in showing the importance of such analysis and the amount of labor and care that is necessary to obtain reliable information.

Soil samples for this purpose were obtained by sending requests to members of the Florida State Florists Association and Soil Science Society of Florida. Samples from areas showing abnormal plant growth and from associated areas showing more nearly normal plant growth were desired. Forty two samples were sent to the clinic.

These samples were analyzed prior to the date of the clinic for some or all of the following: pH, phosphorus, potassium, calcium, and organic matter. Two related samples showing fair and poor Delphinium growth respectively were analyzed at the clinic.

The following data was obtained:

Plant Growth	pH	Phosphorus Lbs. per Acre	Calcium Lbs. per Acre	Organic Matter (percent)
Fair	6.8	230	1456	3.3
Poor	4.6	trace	480	4.5

These soils had been limed just prior to sampling, and the lime had not had time to react and significantly raise the pH of the second sample. The marked difference in phosphorus content and pH indicates a possible cause of abnormal plant growth and suggests the types of amendments

* Chemist and Assistant Chemist, respectively, Soils Department, College of Agriculture, Gainesville.

that should be given consideration. The methods of analysis employed for the above were "glass electrode" for pH, "Truog .002 N H_2SO_4 extraction" for phosphorus, "NH_4Ac extraction-oxalate precipitate titration" for calcium, and "loss on ignition" for organic matter.

Of the other samples submitted to the clinic, the comparative data on several pairs indicated nutrient deficiencies which might be responsible for poor plant growth. In some cases this was merely indicated by the pH of the soil. At alkaline and moderately acid reactions phorphorus and trace elements tend to become difficultly soluble and only plants which are light feeders on these elements or have an exceptional feeding ability can maintain healthy growth. At extreme acidity, high solubility leads to toxic concentrations, and excessive loss through leaching of elements. Thus, as blood pressure and body temperatures indicate the condition of health to a doctor, pH indicates soil health with respect to any plant to the soil scientist, and suggests what nutrient or nutrients need investigation for possible deficiency or excess. Following such a clinical study, the suggested amendments are tried and resultant plant health observed for the final answer. The work is complicated not only by numerous diseases and insects, but by the specific peculiarities of the multitude of plant species which make up Florida agriculture.

FIELD DEMONSTRATION OF THE INCORPORATION OF ORGANIC MATTER WITH THE SOIL

C. E. Bell*

The first task in really putting organic matter such as crop residues, cover crops, weeds, peat or muck, or manure to work is the thorough incorporation of it with the soil. It was deemed of interest, therefore, to hold a demonstration along this line in connection with a symposium on the general subject.

The Rototiller used for this purpose was made available through the courtesy of Mr. W. A. Adair of Jacksonville, State Agent for Rototiller, Inc., and we are deeply indebted to him and to the Company for their fine cooperation in this phase of the program.

In order to make the demonstration as convenient and accessible as possible and in view of the fact that many members of the Florida State Florists Association, meeting jointly with our Soil Science Society this year, were also interested in it, arrangements were made to hold it at the time of the Campus Tour. Through the courtesy of Mr. G. E. Ritchey of the Agronomy Department, it was arranged for on a small area with a fairly heavy growth of rye, weeds, and grasses, adjacent to the Plant Introduction Garden.

Figure 1.—A B1-3 Rototiller, 17", Vegetable Grower Model, in Action. The mat of plant material on the surface of the ground is being uniformly incorporated with the top 4-6 inches of the soil by the action of this implement.

* Associate Soil Chemist, Soils Department, College of Agriculture, Gainesville.

The demonstration left little doubt in the minds of any who saw it that the machine does an excellent job of incorporating quite heavy quantities of organic materials thoroughly with the top five to seven inches of soil. Figure 1 shows two views of this type of equipment in action somewhere in New York where the soil is commonly much heavier than in Florida. Such soil preparation serves the purpose of working the material well into the rooting zone of most plants where it will be somewhat protected against natural oxidation. At the same time it will help to develop a greater depth of active soil which will afford better absorption capacity for both plant food and moisture, and also wider feeding range for plant roots.

SYMPOSIUM: THE "TRACE" OR "MICRO" ELEMENTS IN THE SERVICE OF FLORIDA AGRICULTURE

Auditorium, Chemistry Building, Thursday, May 30, 1940

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INTRODUCTION

R. V. Allison.* Chairman

In view of the extremely important role that some of the so-called trace or micro elements are now known to play in plant, animal, and human nutrition, it is timely indeed that one of the two symposia of the First Annual Meeting of the Soil Science Society of Florida should be devoted to this subject. The program this afternoon will deal with organic matter.

The soils phase of this field of research was established in the state with a most auspicious beginning only a little over a decade ago when copper, manganese, and zinc proved themselves the "three horsemen" necessary to rescue the Everglades of Florida from an agricultural inertia that had defied all efforts up to that time. Copper furnished the answer to complete failure of practically all agricultural plants on the raw, fibrous sawgrass peat that is so characteristic of most of that great area. Treatment with manganese was found equally essential where the high lime peat or muck had been burned or otherwise made too alkaline for plant growth as by marl in the immediate subsoil. Zinc was observed to give its first important impulse to plant growth under raw sawgrass conditions as a combination treatment with copper when it produced an amazing promptness of response by peanuts that was not only as striking as the copper response itself but induced an earlier maturity for the plants receiving the combination treatment by several weeks. This was especially notable where the first treatments were made on freshly broken soil shortly before planting.

These responses have been extended to include boron under certain conditions and have involved, in the the aggregate, an almost endless variety of plants varying from radishes to alfalfa and from sugar cane to citrus. They have also involved an even greater variety of ornamental plants of every description for which Florida is justly famous. In due course they have extended to mineral soils on a widespread basis where these vital trace elements, though present, have been bound up into forms unavailable to plants through excesses of lime in the soil (too high pH) from one source or another or where open sandy soils, so susceptible to leaching, have been treated too continuously with acid-producing fertilizers with the result that the reaction (pH) has been reduced to 5.0 or lower and the soil thus washed free of essential micro elements

* President, Soil Science Society of Florida (1939-40).

as well as numerous others such as calcium, magnesium, and potassium that are equally vital for the normal growth of plants.

The scope of this work to date in the state, insofar as the contributions from the University of Florida are concerned, is well shown by a mimeographed list of references, numbering in excess of two hundred, that recently has been prepared. A limited number of copies of this list are available for those who may be particularly interested in this subject.

As a result of this whole program, there has developed an ever-increasing appreciation of the interlocking character of such studies of soil and plant relationships especially as they impinge on the welfare of animal and man alike through the common channel of nutrition. Consequently, in arranging this symposium we have undertaken to give you a brief picture of how the various segments of this whole field of research are related. This will be done by first discussing the methods of analysis now in common use in this important field and then breaking the main body of the subject matter into those four all-important components, *soil*, *plant*, *animal*, and *man*. Naturally a careful consideration of this sequence is of great importance in the development of our research program for the future.

We will first listen to a discussion of "Recent Plant Responses to some of the Micro Elements on Everglades Peat," by Dr. W. T. Forsee, Jr

RECENT PLANT RESPONSES TO SOME OF THE MICRO ELEMENTS ON EVERGLADES PEAT

W. T. Forsee, Jr.*

The highly organic soils of the Florida Everglades are characterized by both peat and muck types, with ash content varying from as high as 60 per cent in the "Custard Apple" or Okeechobee muck to as low as 8 per cent in the "Sawgrass" peats. The greater part of the soil in this vast area is of the sawgrass type, receiving this name from its native cover of sawgrass. A typical analysis of this soil would show in approximate figures: ash, 10%; nitrogen, 3%; CaO, 3%; MgO, 0.6%; P_2O_5, 0.1%; K_2O, 0.1%; Na_2O, 0.1%; Al_2O_3, 0.6%; Fe_2O_3, 1%; manganese, 0.003%; copper, 0.001%. These figures are only approximate and are based on the results of many total analyses conducted at the Experiment Station by various investigators. Also, the percentages are total amounts and in no way represent the amounts of these materials available to plants. Soils with such a low mineral content would naturally be expected to be deficient in many substances necessary for satisfactory plant growth. Thus, plants should be expected to respond not only to applications of the so-called macro or major elements but to the micro elements as well.

Systematic studies relative to the effect of certain micro elements on the growth of agricultural plants on the peat soils of the Everglades were inaugurated late in 1926. Allison, Bryan and Hunter, in Florida Experiment Station Bulletin 190, made a preliminary report on this work in which copper and manganese gave the most outstanding results, though limited responses to zinc were apparent. In other studies that immediately followed, zinc gave very striking results with certain plants when properly combined with copper. As a result of these preliminary studies, copper and manganese in particular soon began to find a very important place in the agriculture of the Everglades. A continuation of these investigations is reported in the Florida Experiment Station Annual Reports, 1927 to date by Allison, Neller, Wedgworth, Townsend and Robertson and by Townsend in Florida Experiment Station Bulletin 336. Boron has been added to the list of micro elements found necessary for plant growth in these soils under certain conditions. The importance of zinc has also been greatly expanded by later studies.

A large portion of the more recent investigations at the Everglades Experiment Station on plant response to the micro elements has been carried out under greenhouse conditions. A preliminary report of some of these studies will be given in this paper.

In all of the greenhouse experiments the soil was spaded, well mixed and freed from roots and trash and placed in glazed earthenware jars. Each jar contained a uniform weight of soil and a uniform soil moisture was maintained by weighing and watering with distilled water. Pure chemicals were used for soil treatments and a uniform application of

* Associate Chemist, Everglades Experiment Station, Belle Glade, Florida.

phosphorus and potassium was made in addition to the micro element variations. Treatments were carried out in triplicate and the jars were arranged in random distribution.

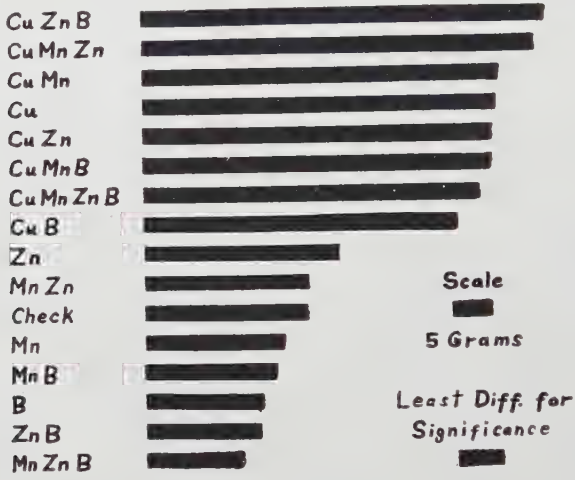

Figure 1.—Graphic representation of yields of corn (total plants) grown on Everglades peat treated with various micro elements and combinations of these elements.

The results of the first preliminary experiment are represented graphically in Figure 1. Treatments included applications of copper, manganese, zinc and boron and all possible combinations of these elements. The bars represent the oven-dry weight of corn plants removed from the various treatments. The item of most striking significance in this figure is the large difference between those treatments which included copper and those which did not. According to "Student's" Method of statistical analysis the differences between the copper and non-copper treatments are highly significant. (Odds of more than 900 to 1 that the differences are not due to chance.) The copper response is even more highly significant when the fact is considered that the soil used for this experiment was well decomposed sawgrass peat from a cultivated area of the Experiment Station farm. This area was adjacent to a group of fertility plots and the soil perhaps contained added traces of these micro elements due to wind movement of soil and flooding.

In order to eliminate these sources of copper contamination, the soil for subsequent experimental work was obtained from an area of raw undeveloped land lying outside the dikes which surround the cultivated area of the Station farm. Distilled water was used to maintain the proper moisture level in the jars. Copper applications were made in the form of copper sulfate.

The following photographs (Figs. 2-8) illustrate the effect of copper as a soil amendment on the growth of plants in sawgrass peat soil under greenhouse conditions.

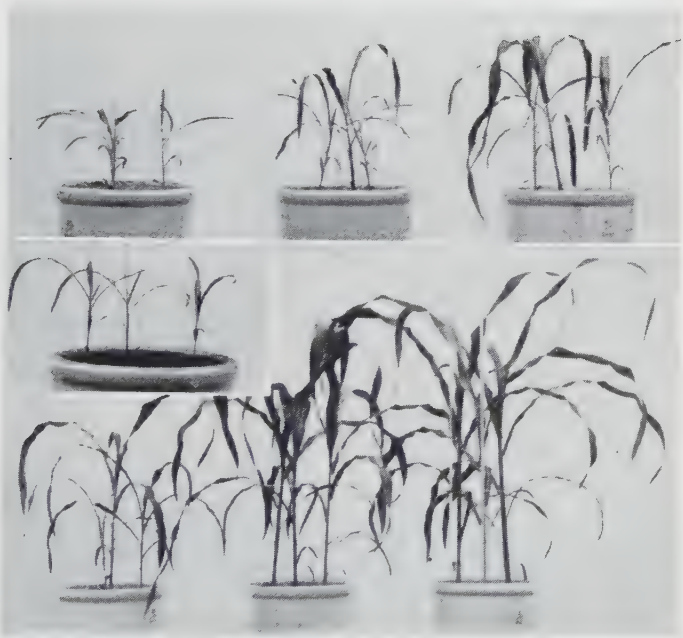

Figure 2.—In order to determine the optimum application of copper, the above cultures were given treatments of 0, 1, 5, 10, 25, 50, 100, 200 and 300 parts per million of copper in the form of copper sulfate. Increased yields of shallu were obtained with increasing amounts of copper up to 50 ppm. Beyond this limit of copper there were no significant differences in yield. The top row, reading from left to right, represents copper applications of 0, 1 and 5 ppm. and the bottom row represents 10, 25 and 50 ppm. Inset shows a closeup of the copper deficient plants growing in one of the untreated cultures. Note the drooped leaves, the dead leaf tips and the rolled condition of the younger leaves emerging from the whorl. The age of the plants at the time these photographs were made was 32 days.

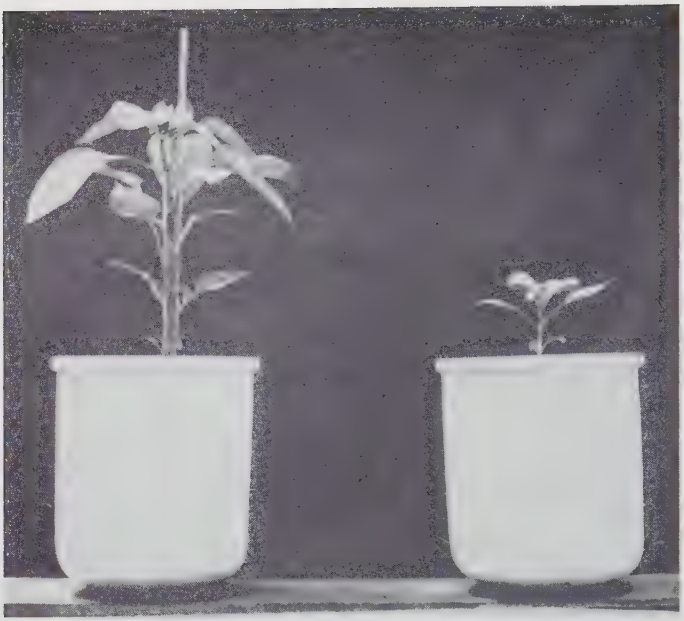

Figure 3.—Young eggplants first evidenced copper deficiency about two weeks after germination. This photograph shows the contrast between copper (right) and check (uncoppered) treatments 82 days after planting. Copper deficiency symptoms in eggplant are very striking, the untreated plant being severely stunted in appearance, chlorotic with green spots on the leaves and marked yellowing and browning at the leaf tips.

Figure 4.—A photograph of 82 days old pepper plants with (left) and without copper. Although these plants did not evidence deficiency symptoms until about four weeks after germination, when they did appear they were very pronounced. The severity of the symptoms is well shown in the inset where the plant is stunted, the leaves cupped, crinkled and twisted and the general appearance somewhat similar to mosaic.

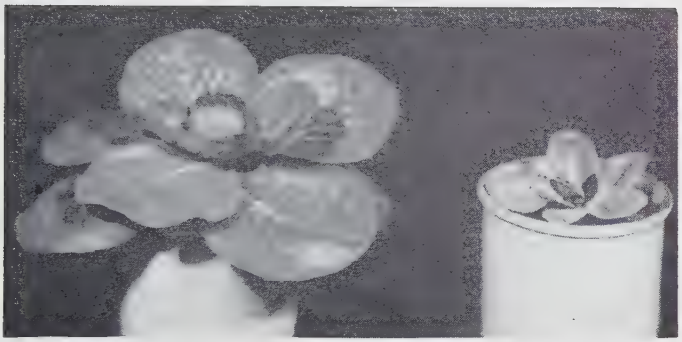

Figure 5.—Cabbage showed copper deficiency symptoms within five days after germination. The copper deficient plants became chlorotic and stunted in general appearance. Copper deficient plants did not attain enough growth to produce heads. The age of the plants at the time this photograph was made was 41 days.

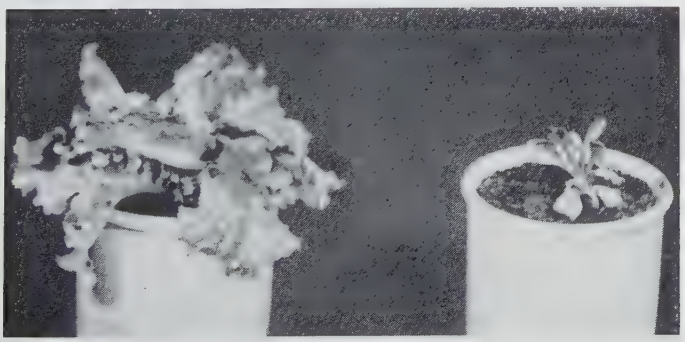

Figure 6.—Lettuce exhibited copper deficiency as soon as the first two leaves appeared. Plants receiving no copper were invariably smaller and after several days the symptoms became very severe. The above photograph was taken 41 days after planting. Growth of the copper deficient plant had ceased entirely and the leaves were elongated and cupped and had lost practically all their green color, being almost white.

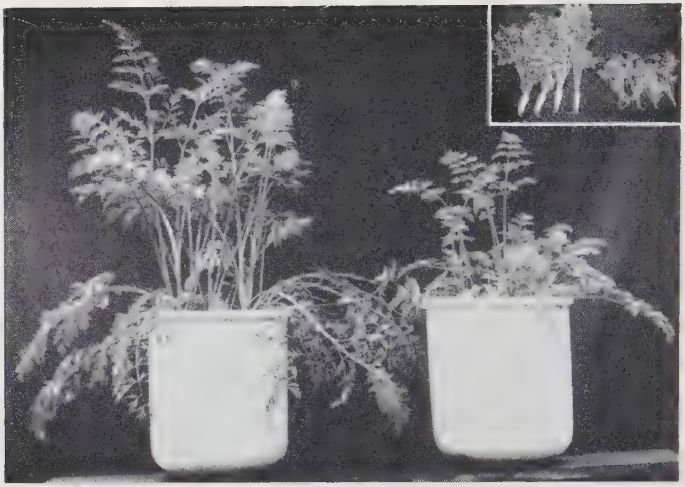

Figure 7.—Carrots began to show differences in growth between coppered and untreated cultures about two weeks after germinations. The above photograph, with the plants in place, was taken 41 days after planting; left, treated and right, untreated. The plants shown in the inset, in the same order of treatment, were removed from the soil after 82 days and show the same striking differences in both top and root development.

Figure 8.—Copper response on celery growing in raw, Everglades peat first became evident about four weeks after germination. The above photograph was taken 82 days after the seeds were planted. The tremendous response of the plants to copper is evidenced by the poor color and stunted growth in the untreated culture (right).

The addition of the micro element copper to Everglades peat is thus necessary for the normal growth of a great variety of agricultural plants and in most cases determines the difference between a good yield and a complete crop failure. The importance of copper sulfate as a soil amendment on Everglades peat cannot be over-emphasized and its economic value to growers in that area is inestimable.

The author wishes to thank Mr. Len S. Jones for his help in the preparation of the photographs and in the greenhouse work involved in these experiments.

SOME PHYSICAL AND CHEMICAL METHODS USED IN DETERMINING THE TRACE ELEMENT CONTENT OF SOIL, PLANT AND ANIMAL MATERIALS

L. H. Rogers and R. C. Hughes*

Any discussion dealing with trace elements should first define what elements are being included in this category. For the purposes of this paper, the trace elements are being defined as all elements other than the classical ten elements considered essential for growth of plants. Figure 1 shows a periodic table with an indication of the present status of our knowledge regarding the biological essentiality of some of the elements.

The study of the effects of the trace elements on plants and animals, the determination of their natural occurrence and distribution in soils, plants and animals, and studies on their role in biological processes require that large numbers of samples be analyzed for these elements. It is the purpose of this paper to discuss some of the procedures used in performing these analyses.

The name "trace" or "micro" elements indicates that only minute amounts of these elements occur in plants or animals. Hence ordinary chemical methods of anaysis are not, in general, applicable because they are designed to analyze for larger quantities. In recent years, a new field of chemistry called microchemistry, because it deals with analysis of exceedingly small quantities of elements, has been developed to cope with these problams. In some cases this has merely involved the use of very small containers and very sensitive balances, and exacting attention to manipulation, but utilizing essentially the same reactions as are used in ordinary chemical analysis. In other cases, new chemicals and new techniques have been developed, or well known physical principles have been adapted for microanalysis.

Since there are literally dozens of different chemical and physical methods of microanalysis, this paper is to be limited to a discussion of only two procedures. One of these is chemical, the other physical. These are not necessarily the most important procedures, they are merely newer procedures with which we happen to be more familiar. The chemical procedure which we will discuss involves the use of dithizone; while spectrography has been used as an example of a physical procedure. It should be pointed out that each procedure discussed here has its own particular field in which it is best suited. Furthermore, in some cases a combination of these two procedures, or combinations of each of these with others may be desirable.

* Associate Biochemist and Research Assistant, respectively, Soils Department, Florida Agricultural Experiment Station, Gainesville.

Dithizone [1] is a complex organic compound which has the property of being soluble in chloroform and other organic solvents, but is insoluble in water. Its peculiar usefulness lies in the fact that it forms highly colored compounds with various chemical elements, and the compounds thus formed are likewise soluble in chloroform, but not in water. It makes possible, therefore, the extraction of a relatively small amount of some metal from a large amount of water solution into a small amount of chloroform solution, thus serving to concentrate the element in question. Furthermore, the resulting chloroform solution is highly colored, depending on the metal which is present. Brilliant yellow, red or violet colored compounds are formed with a dozen or more metals. Figure 2 shows a periodic table and indicates the elements that react with dithizone. Of course, since agricultural materials contain many metals, the use of dithizone directly, for example on an extract of a soil, would separate out a mixture of the metals contained in the extract. Obviously, such a mixture would be of little value. It is fortunate, however, that it is possible to limit the elements that dithizone will extract by resorting to other means, for example adjustment of the acidity of the water solutions.

The most useful range of dithizone methods is from 1 to 200 micrograms [2] of metal, and the errors vary from less than 1% to 5%, depending somewhat on the amounts to be determined.

To make an analysis with dithizone, 3 steps are involved, namely (1) sample preparation (2) isolation of the element sought and (3) its final determination. A brief discussion of each of these steps follows:

1. Preparation of the sample usually involves the destruction of organic matter in the sample. This is done either by ashing in an electric furnace at red heat, or by the use of oxidizing acids. In the former case the resulting ash is dissolved in acid, and is then ready for the next step.

2. Isolation of the element sought requires the greatest attention to attainment of the proper conditions. The dithizone compounds are simultaneously formed and extracted in most cases by shaking water solutions of the metals at the proper acidity with chloroform solutions of dithizone. The green color of the excess dithizone modifies the color of the extracted dithizonates with the production of beautiful mixed colors ranging from green through blue, purple and crimson to red. The various metals of the dithizone group react at different optimum degrees of acidity of the water solution. Therefore the pH governs the order in which the metals are extracted. Other factors in addition to acidity affect these separations, but will not be discussed here.

3. The final determination of the metal after it has been extracted from its aqueous solution and separated from other metals remains to be considered. Here again, various procedures have been used, but only

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[1] The discussion given here follows (except in much less detail) an article by H. J. Wichmann, "Isolation and Determination of Traces of Metals" which appeared in J. Ind. Eng. Chem., Anal. Ed. **11**, 66 (1939).

[2] A microgram is one millionth of a gram.

one modification of a colorimetric procedure is to be discussed. In this procedure (known as the mixed color method) the metal (lead has been determined more extensively than any other metal in this manner) is extracted from the aqueous solutions at optimum acidity with an excess of dithizone in chloroform solution. This excess of dithizone is not removed but is allowed to modify the color of the extracted dithizonate. Thus, in the case of lead, a series of colors from green to red may be arranged with intermediate blues, purples and crimsons; hence the term "mixed colors." The hue of the unknown is matched against the hue of a standard series of colors. With a little practice, analysts become very expert at matching these hues. Very rapid and accurate results may be obtained in determining the lead of lead spray residues. Several procedures other than the one here described have been used for the final determinations.

This brief description of the dithizone system of analysis indicates that excellent results can be obtained with simple apparatus. More elaborate apparatus may be used (for example, a photoelectric colorimeter) to increase the speed of analysis. Careful choice of the conditions of extraction is essential for satisfactory results.

As pointed out above, there are many chemical procedures for making microanalyses other than the dithizone system considered here. This was chosen because it is one of the newer and more sensitive techniques. Rapid developments are now taking place in this field—newer and better organic reagents may be expected due to the increased interest and importance of the field. The dithizone system of analysis is applicable to all types of materials—soils, plants, animals and other agricultural materials.

SPECTROGRAPHY

Turning now to a discussion of spectrography and its field of application: A spectrograph is an instrument for breaking light up into its various component parts, just as rain particles break up the sunlight into a rainbow. It consists of a slit through which the light passes, two lenses for focusing the light and a prism which disperses the light into a spectrum. The resulting spectrum is then photographed. The instrument in use at the Florida Agricultural Experiment Station is called a Littrow spectrograph and is illustrated in figures 3 and 4.

We are engaged in two types of analysis with this instrument. These are (1) a semi-quantitative procedure and (2) a precision quantitative procedure. The first is used for rapid analysis for a large number of elements where a general idea of the composition of a material and a crude estimate of the proportions present is desirable. This procedure has been used by us for survey analyses of soils, fertilizers, plant and animal tissues and other agricultural materials, as a guide for later work and for rough comparisons. The procedure used will be apparent from some of the later figures.

The precision quantitative procedure requires the use of an auxiliary instrument known as a microphotometer and shown in figure 5. This instrument is only a special form of projector which gives an enlarged image of the spectrum on a screen behind which is a photo-electric cell

which measures the density of the line in question. Using this procedure, a precision of 10% or better may be attained.

Before discussing the problems being studied, it seems pertinent to point out certain advantages of analysis by spectrography. These are:

1. *Speed.* Using the rough estimate procedure, an analysis for 30 elements may be completed in less than two hours. This is an average of about 4 man-minutes for each analysis.

2. *Sensitivity.* About 70 of the 92 elements can be detected with a sensitivity varying from 1 part per million to 1 part per 100,000 as shown in figure 6. (Taken from Lundell and Hoffman.[3])

3. *Certainty of identification.* With an instrument having good dispersion, coincidence of lines is so rare as to be negligible; furthermore, nearly all elements have several sensitive lines, thus enabling the analyst to check himself.

4. *Appearance of unusual or unsuspected constituents.* Since all the atoms present in the source which are excited emit their characteristic wave lengths, these are recorded on the plate, and unsuspected elements thus manifest themselves.

5. *Small sample requirements.* An analysis may be made with about 10 mg. of material. When working with certain animal tissues, this is particularly advantageous.

6. *Permanent record.* The plates may be filed, and if at some future date some question arises concerning any particular analysis, it may be checked quickly. Furthermore, several persons may confer regarding any point.

For the purposes of this paper, the problems being studied may be discussed according to the nature of the materials, namely: (1) soils and waters (2) fertilizers, soil amendments materials, spray materials and mineral supplements for animals (3) plant tissues and (4) animal tissues. Of prime interest here is not analysis of these materials per se, but rather in their interrelationship, the influence and availability of the trace elements in soils, their assimilation by plants, and in turn by animals and man.

1. The purpose in analyzing soils and waters-for-agricultural-use is to determine the distribution and availability of the trace elements in these materials for purposes of evaluating them with regard to the essential (as well as other) trace elements, and also to determine possible toxicities. A useful by-product of such a study is in connection with a survey of the geologic resources of the state. In a recently completed study of the distribution of some macro and micro elements in some Florida soils, it was found that in general the poorly drained soils of peninsular Florida contain greater proportions and a greater variety of both macro and trace elements than do the well drained soils. Figure 7 shows a portion of the ultra-violet spectrum of a Parkwood soil and a St. Lucie soil analyzed in this study. Note the order in which these spectra are taken. This illustrates the rough estimate procedure which

[3] Lundell, G. E. F., and Hoffman, J. I., Outlines of Methods of Chemical Analysis, John Wiley & Sons, New York, N. Y. (1938).

was mentioned previously. The presence of zirconium, nickel, titanium and copper in the Parkwood sample and the virtual absence of all these elements except titanium in the St. Lucie soil is interesting. (These elements are not necessarily essential to plant growth.) Parkwood soils are among our best soils for citrus—St. Lucie soils are among the poorest.

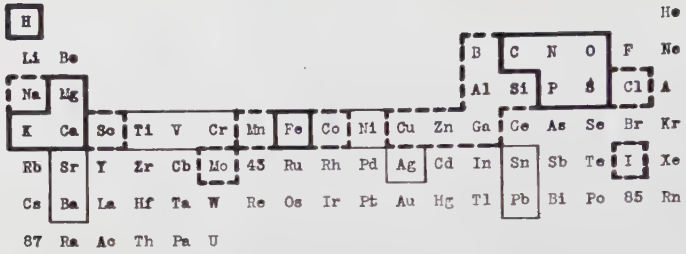
2. In the analysis of fertilizers, soil amendment materials, etc., of interest is the possibility of toxicity as well as stimulating effects of the trace elements, contained accidentally, on plants and animals. In a study conducted several years ago on fertilizer materials, it was found that of the four general types of materials studied (lime, phosphate, potash and nitrogen) the phosphatic materials contained a greater variety and larger proportions of the trace elements than did the other classes of materials studied. Figure 8 shows a portion of the ultra-violet spectrum of a phosphate fertilizer and a potash fertilizer which were analyzed in this study.

3. In the study of plant tissues, we are interested in determining the essential trace elements for normal plant growth, the functions of these trace elements, tolerances, effects of excesses, and differences in requirements by different species as well as by different organs in any one plant species. The studies will involve very painstaking solution culture work in the greenhouse, carefully controlling all factors involved, and utilization of the spectrograph to control the quantity of trace elements. Figure 9 shows a portion of the visible spectrum of a sample of Valencia orange juice ash. Note the presence of the metal strontium, barium, vanadium and chromium.

4. There is insufficient time to discuss in any detail the problems with animals. There are involved here, as in plant studies, determination of (1) normal requirements, (2) tolerances, and (3) functions of the trace elements.

SUMMARY

Two methods of analysis of agricultural materials for trace or micro elements have been discussed. Some of the advantages, disadvantages and precautions for each procedure have been mentioned, not with the intention of emphasizing the difficulties, but to indicate the complexity of factors that are involved. The complexities are not insurmountable, however, and it is felt that reasonable progress is being made in solving some of the more pressing problems in this field of analysis.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He
Li Be
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Rb Sr Y Zr Cb Mo 43 Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po 85 Rn
87 Ra Ac Th Pa U

Heavy solid blocks enclose elements long known to be essential.
Heavy broken blocks enclose elements whose essentiality is fairly well established for certain organisms.
Light solid blocks enclose elements frequently detected in biological materials, but whose essentiality as yet remains unproved.

Figure 1.—The biologically essential elements.
(adapted in part from Steinberg)

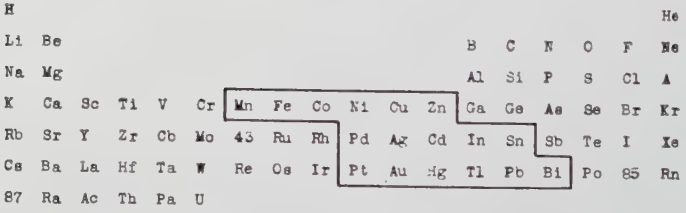
H
He
Li Be
B C N O F Ne
Na Mg
Al Si P S Cl A
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Cb Mo 43 Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po 85 Rn
87 Ra Ac Th Pa U

Figure 2.—Elements that react with dithizone.
(enclosed by solid line)

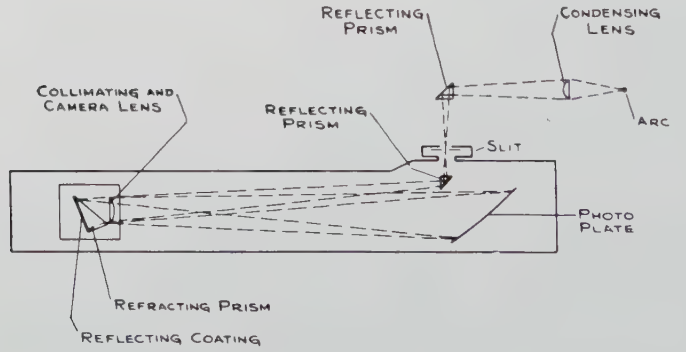

Figure 3.—Optical system of Littrow type spectrograph.

Figure 4.—The Littrow type spectrograph with operator in process of focusing the instrument preparatory to making a series of exposures from the arc on his right in which the sample is "burned".

Figure 5.—A microphotometer which is used for measuring the intensities of spectral lines on photographic plates by way of determining the amounts of various elements in the sample under examination.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	A
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Cb	Mo	—	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	—	Rn
—	Ra	Ac	Th	Pa	U												

* Also elements 58-71.

Heavy solid blocks inclose elements for which test is of high sensitivity (of the order of 1 part in 1,000,000).

Heavy broken blocks inclose elements for which test is insensitive. For the detection or determination of small percentages of these, special procedures are usually required.

Elements not inclosed in blocks are those for which test is of average sensitivity (on the order of 1 part in 100,000). Of these, elements adjacent to elements of high sensitivity are somewhat more sensitive than the average, while those adjacent to the insensitive elements are somewhat less sensitive than the average.

Figure 6.—Sensitivity of spetrochemical tests for the elements. (in wave-length range 2000-10,000 Angström units)

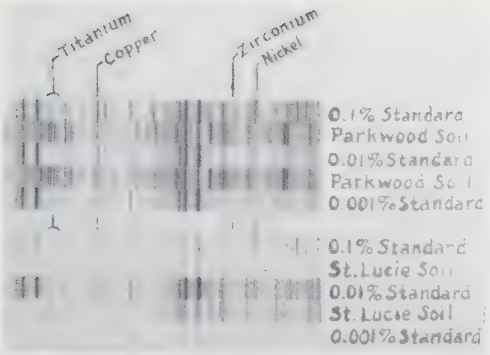

Figure 7.—A portion of the ultra-violet spectrum of two Florida soils (Parkwood and St. Lucie) together with those of standard materials for comparison.

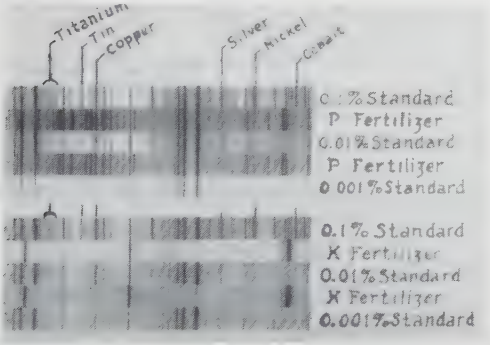

Figure 8.—A portion of the ultra-violet spectrum of two fertilizer materials, one emphasizing phosphorus and the other potassium, together with those of standard materials for comparison.

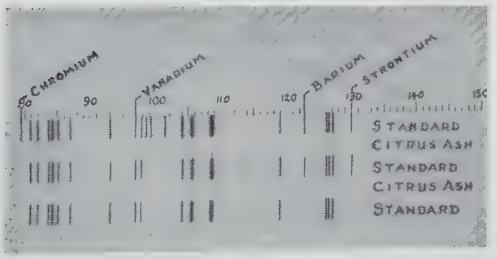

Figure 9.—Spectrum photographs of a sample of Valencia orange juice ash together with those of standard materials for comparison.

THE TRACE ELEMENT CONTENT OF SOME IMPORTANT SOILS—A COMPARISON

R. V. Allison* and L. W. Gaddum†

The rapidly increasing interest in the significant role of certain of the "trace" or "micro" elements in plant, animal, and human nutrition around which this symposium is centered, makes it very desirable for us to examine the composition of our Florida soils just as critically as possible with respect to their content of these elements. Indeed it would seem very much worth while to compare their makeup, from this standpoint, with that of well-known types from other parts of the country, especially since our more pervious soils down here on the Southern Coastal Plains are probably more exposed to change by leaching than in any other section. Accordingly we are glad to be able to give you a preliminary comparison of the trace element content of a number of typical Florida soils to those of eleven important profiles assembled from widely different parts of the United States which, in fact, do represent some of our best agricultural lands.

SOURCE OF THE SOILS STUDIED

In view of the fact that the "Out-of-State" soils, as well as most of the Florida soils used in this comparison, have been described in the literature in considerable detail, they will be discussed at this time only sufficiently to make their principal characteristics conveniently available to the reader. To the extent that it may seem desirable, the descriptive material will be drawn directly from the original texts.

A. *Florida Soils*

The spectrographic analyses of Florida soils presented below are taken, for the most part, from Bulletin 341 [1] of the Florida Agricultural Experiment Station. For the purposes of the principal comparison, however, only the "cultivated" soils are considered. This reduces the total number of samples used for this purpose from 77 to 54 for the topsoil and from 55 to 35 for the subsoil.

The only Florida soils included that are not reported on in bulletin No. 341 are the complete profiles of Everglades sawgrass peat and Okeechobee muck collected in the neighborhood of Lake Okeechobee. Both of these organic soils are described in brief detail at all the depths sampled. The distribution of all the samples, by county, is shown on the outline map of the State in Figure 1 which is adopted, with appropriate modifications, from bulletin 341 [1], page 6.

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† Formerly Biochemist, Soils Department, University of Florida; now Chairman, C-2, Man in the Physical World, General College, Gainesville.

[1] Rogers, L. H., O. E. Gall, L. W. Gaddum, and R. M. Barnette; Distribution of Macro and Micro Elements in Some Soils of Peninsular Florida; Bul. 341, Florida Agricultural Experiment Station, 1939.

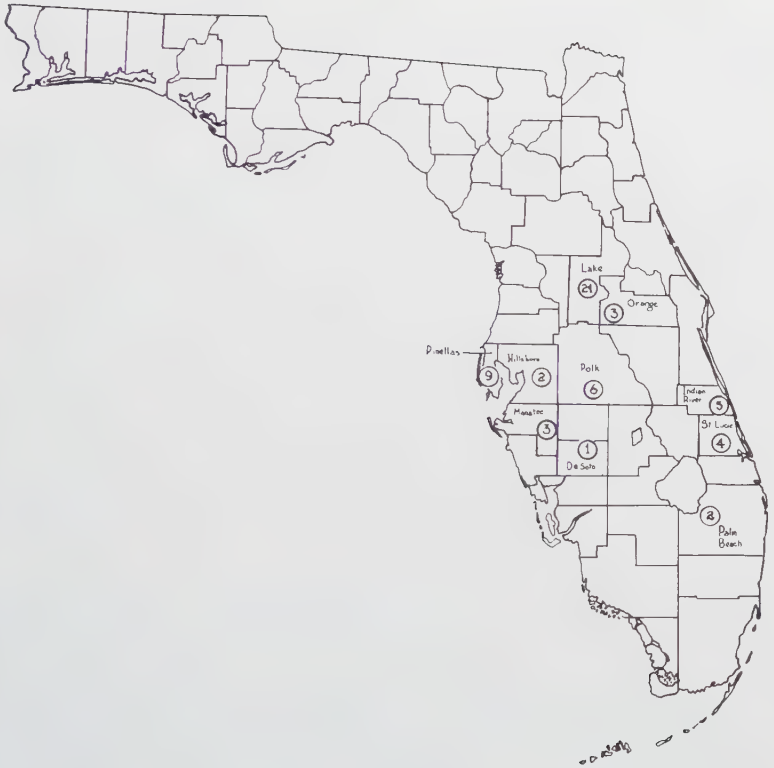

Figure 1.—Number and distribution of Florida soil samples used in the present comparison with out-of-state soils.

In all, then, the following soil series from Florida are represented in this general comparison: Norfolk, Orlando, Parkwood, Eustis, Portsmouth, Scranton, Blanton, Lakewood, Everglades Peat, and Okeechobee Muck. Only the topsoil and subsoil (sub-surface) are reported for the Florida mineral soils since this was the limitation as to depth of sampling decided upon at the time this particular study was made. Standard profile samples are now being collected of all important soil types in the State and analysis will be more largely upon this basis in the future, at least from the standpoint of soil type characterization in support of the soil survey. This data will also serve as excellent background information for systematic soil fertility studies. Concerning the Florida soils reported on, the authors of Bulletin 341 [1] had the following to say on page 7 of that publication:

> The Norfolk, Eustis, Lakewood, Orlando, and Blanton soils are all well drained. The Norfolk soils have gray or yellowish-gray surface layers, 3 to 5 inches thick, over yellow subsurface layers. The Blanton soils are similar to Norfolk soils but have pale yellow to yellowish-gray subsurfaces. The Orlando soil differs from the Blanton in that the surface layer is dark gray and extends to depths of 12 to 18 inches. The Eustis contains considerable red which

imparts a brownish-gray or grayish-brown color to the surface and a reddish-yellow or yellowish-red color to the subsurface. The Lakewood soil has a light gray surface layer about 3 inches thick over a white subsurface which changes abruptly to yellow at depths of 12 to 24 inches.

The Portsmouth, Scranton, and Parkwood soils all have poor natural drainage. The Portsmouth soil has a dark gray or black surface layer 8 to 12 inches thick over a light gray to white subsurface. The Scranton soil differs from the Portsmouth in that the subsurface is yellowish-gray to yellow. The Parkwood soils have dark gray or gray surface layers of variable thickness over light gray or yellowish-gray subsurfaces, which grade into yellow, gray, and brown sandy clay subsoils or directly into marl at depths usually within four feet of the surface.

As noted on the same page of bulletin No. 341 as the reference quoted above, more extensive information on these soils is available in Florida Experiment Station Bulletin No. 334, "The Soils of Florida," by J. R. Henderson.

The profile description of the Everglades peat and Okeechobee muck with volume weights for most of the depths are as follows:

Everglades peat, derived from sawgrass. Profile taken from S. E. sector, Everglades Experiment Station, Section 3, R-37E, T-44 S. (Lab. No. 16243)

(1) 0″-4″, dark brown, finely fibrous to granular sawgrass peat, dry and loose. (Volume weight,[2] 0″-2.5″, 16.21 lbs.); (2) 4″-15″, dark-brown, fibrous matted sawgrass peat mottled with a considerable matrix of dark, fine grained material which tends to increase somewhat with depth. (Volume weight, 7″-11″, 7.34 lbs.); (3) 15″-19″, dark brown to black, slightly plastic, apparently of sedimentary origin in part, containing much stringy fibrous sedge peat. Generally similar in color and decidedly more homogeneous in character than the dark striations referred to in No. 2 above. (Volume weight 15″-19″, 11.15 lbs.); (4) 19″-26″, intermediate between fibrous and plastic, being markedly more fibrous than No. 3 above or No. 5 below, consisting of a matrix of dark, finely fibrous, sedge peat that contains an abundance of soft, loose, stringy rhizomes. (Volume weight 20″-24″, 9.84 lbs.); (5) 26″-30″, comparatively dense, plastic layer, matrix material apparently of sedimentary origin for most part, containing a considerable amount of stringy fiber through it. (Volume weight, 26″-30″, 12.0 lbs.); (6) 30″-40″, characterized by a greatly increased content of brown fibrous peat and marked decrease of fine, plastic matrix material. (Volume weight, 33″-37″, 8.42 lbs.); (7) 40″-50″, increase in yellow fibrous peat until at 48″-50″ there is a 2-inch layer of pure, straw-colored, highly fibrous sawgrass peat, closely matted. (Volume weight, 45″-49″, 6.48 lbs.); (8) 50″-74″, changes rather abruptly at 50″ to fibrous, stringy peat embedded in a matrix of dark, finely fibrous to sedimentary material; (9) 74″-78″, dark fine-grained material with an admixture of matted fiber lying directly above the rock and mixed with marl or rotten limestone at the interface. Limerock at 78″.

Okeechobee Muck, taken from area west of South Bay, N. W. ¼ Section 14, R-36E, T-44 S. Water table slightly more than 4 feet below surface of soil at time of sampling. (Lab. No. 16245)

(1) 0″-9″, surface 2½″ black to grayish-black dry granular muck, over dense, black, angular, lumpy to cloddy, amorphous material; cracks and fissures extend to depths of 4 feet and into the layer of fibrous sawgrass peat at the

[2] Volume weight, pounds per cubic foot after oven-drying, for such depths as it was found practical to take samples for this purpose.

lower levels; (2) 9″-13″, muck containing considerable quantity of brown, rather platy peat poorly decomposed, more or less stratified, in a matrix of heavier, more plastic material. Varies considerably but found locally in all examinations; (3) 13″-26″, dense, black, plastic, sedimentary peat, moist and very sticky. (Volume weight, 17″-19.5″, 19.17 lbs.); (4) 26″-33″, grading from above rather sharply into densely fibrous, raw sawgrass peat more or less platy or laminated in structure. (Volume weight, 28″-30.5″, 9.38 lbs.); (5) 33″-58″, more plastic in character than above, consisting of an admixture of sedimentary matrix with some striations of brown, more or less platy fiber through it. Below 42″ the darker material appears to be somewhat more plastic and dense but the striations of brown fiber appear about the same in proportion and character. (Volume weight, 35″-37.5″, 12.4 lbs.; 47″-49.5″, 13.25 lbs.); (6) 58″-72″, increase in fiber content over 5, of a characteristically stringy type derived in large part from *Scirpus sp.*, dark in color in the upper part of the stratum to almost a pure yellow below 72″. (Volume weight, 65″-67.5″, 7.34 lbs.); (7) 72″-77″, stratum of dense, matted, poorly decomposed sawgrass peat, yellow, very fibrous. (Volume weight, 74″-76.5″, 6.88 lbs.); (8) 77″-94″, very dark brown, fibrous sedge peat with content of dark finely divided matrix increasing with depth. Darker and more fibrous and matted below with appearance of dark marly debris at lower depth; (9) 94″-104″, dark plastic, contains considerable sand at the interface with the rock. Sedimentary peat embedded in stringy to matted fibrous plant remains in upper part of stratum. Limerock at 104″.

B. *Out-of-State Soils*

Eleven out-of-state profiles that represent the dominant soils of the first ten Erosion Experiment Stations established by the Department of Agriculture, during the period 1928-1933, in widely different parts of the United States, are used in this comparison.[3] They are about as typical of soils in other sections of the United States as any that could be selected and, of course, carry added significance in a trace element study of this nature in view of the extensive investigational and analytical work that already has been done on them.

The distribution of these soils and the approximate areas each represents are shown on a map of the United States in Figure 1 where their type names are to be found in the legend. While these areas, delineated in such a general way, may include other types in the same series and limited areas of other soil series as well, still the specific types indicated as dominant for each area probably represent, in the aggregate, for all areas, nearly one hundred million acres.

The origin and principal characteristics of the out-of-state soils have been briefly summarized in three Technical Bulletins[4 5 6] of the U. S. Department of Agriculture from which we quote as follows:

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[3] These profile samples were made available for this study through the courtesy of Dr. H. G. Byers, Chief, Division Soil Chemistry and Physics, U. S. Department of Agriculture, as supplied to him by the workers at the various Erosion Experiment Stations referred to as the source of these materials. The Senior Author, as Chief of the Division of Soil and Water Conservation Investigation in the Bureau of Chemistry and Soils and later in the Soil Conservation Service, was in charge of these stations from 1933 to 1936, succeeding H. H. Bennett. Most of these samples were taken at the time the stations were started and are an identical part of those used by Middleton, Slater, Holmes, and Byers in physical and chemical studies, including trace element analysis, referred to below.

[4] Middleton, H. E., C. S. Slater, and H. G. Byers; Physical and Chemical

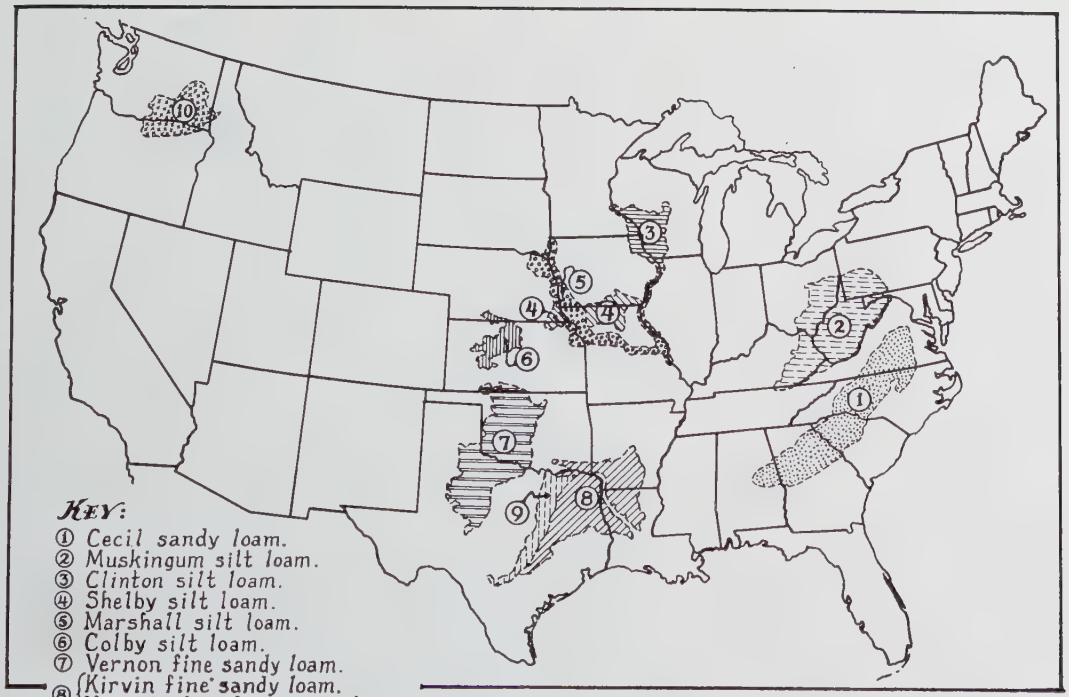

Figure 2.—Approximate geographical distribution of the out-of-state soils used in this study for comparison with Florida soils with respect to trace element content.

(1) The Cecil sandy loam is a lateritic soil derived from granite, gneiss or schist. The colloid is of low silica-sesquioxide ratio, and the profile is markedly variable in texture. It was described by Mr. J. M. Snyder as follows: From 0 to 6 inches, the A horizon of light-brown sandy loam containing very little organic matter but more than either horizons B_1 or B_2. The surface soil in most places is friable and very easily worked unless it is eroded so that only a few inches of surface soil remain. (2) From 6 to 32 inches, the B_1 horizon of red clay loam which is very uniform and compact. (3) From 32 to 60 inches, the B horizon of red clay loam with brown mottlings. This material is very compact when exposed and has a tendency to crack.

(2) The Muskingum silt loam is a gray-brown podzolic soil with an immature profile which grades into the weathered parent shales. The profile is markedly variable and was described by Mr. E. B. Deeter as follows: (1) (a) From 0 to 1 inch, light grayish-brown silt loam (when dry), mixed with grass roots and organic matter. When wet, the color is a fairly dark brown. This was mixed to form one sample with (b) from 2 to 7 inches, yellowish-brown silt loam, with small pieces of shale in small to almost negligible quantity. Very compact and puddles easily. In fields, the dry soil is inclined to crust, and in this condition water tends to run off rather than to percolate into the soil. (2) From 8 to 13 inches, yellow silty clay loam with very faint mottling of gray or light yellow. Contains small pieces of black material (manganese?). Compact and difficult to penetrate. (3) From 14 to 24 inches, compact yellow silty clay, mottled somewhat with gray. Fragments of shale are present. (4) From 25 to 46 inches, light reddish-yellow silty clay, with faint mottlings of gray. Very compact, and shale is abundant. (5) From 47 to 72 inches, heavy dense gray clay with some mottlings of yellow. Shale is present but not abundant.

(3) The Clinton silt loam is a gray-brown podzolic soil, developed on loessial material relatively unweathered. No marked differences of texture are shown by the various horizons. The profile was described by Mr. R. H. Davis as follows: (1) From 0 to 8 inches, dark-brown heavy silt loam; (2) from 8 to 20 inches, yellowish-brown granular heavy silt loam; (3) from 20 to 32 inches, dark grayish-yellow friable silt loam; (4) from 32 to 44 inches, splotched yellow and gray friable silt loam; and (5) from 44 to 66 inches, sandy clay splotched brick-red and gray, soft red sandstone and flint stone present.

(4) The Shelby silt loam is a Prairie soil developed on Kansan drift. Some loessial material is present in the surface soil, and calcium carbonate is found in the lower horizons. The profile was described by Mr. R. E. Uhland as follows: (1) From 0 to 7 inches, a very dark brown surface soil; (2) from 8 to 12 inches, a drab-brown subsurface soil, containing some mottling; (3) from 12 to 20 inches, yellowish-brown heavy very sticky plastic clay; (4) from 20 to 24 inches, lighter-brown material than in layer 3, much less plastic, with a few small lime concretions (a transitional zone); (5) from 24 to 48 inches, a chalky layer containing many lime concretions (some of which, occurring at a depth of about 4 feet, are extremely large), many gravel of different sizes, and an occasional sand pocket; and (6) from 60 to 84 inches, rust-brown joint clay which breaks readily into cubes ranging from 1 to 1½ inches in diameter. The material caves very badly. Very few lime concretions occur at this depth.

(5) The Marshall silt loam is a Prairie soil developed on loessial material. Textural differences are slight within the profile which was described by Mr.

Characteristics of the Soils from the Erosion Experiment Stations; Tech. Bul. 316, U.S.D.A., (1932).

[5] Middleton, H. E., C. S. Slater, and H. G. Byers; The Physical and Chemical Characteristics of the Soils from the Erosion Experiment Stations—Second Report; Tech. Bul. 430, U.S.D.A., (1934).

[6] Slater, C. S., R. S. Holmes, and H. G. Byers; Trace Elements in the Soils from the Erosion Experiment Stations, with supplementary data on other soils; Tech. Bul. No. 552, U.S.D.A., (1937).

G. W. Musgrave as follows: (1) From 0 to 13 inches, dark-brown silt loam which becomes plastic and cohesive when wet but has good natural drainage, and when dry is readily tilled; (2) from 13 to 24 inches, light-brown silt loam; (3) from 24 to 45 inches, material showing occasional grains of sand and slight evidence of drift; and (4) from 45 to 71 inches, rather gritty yellow silt loam (glacial drift).

(6) The Colby silty clay loam is a Chernozem soil developed on loessial material with a low degree of differentiation within the profile. Calcium carbonate is present in all horizons. The particular profile examined from the experiment station at Hays, Kansas, appears to be modified somewhat by the presence of material derived from the limestone shales of the Fort Hays formation. This profile was described by Mr. R. H. Davis as follows: (1) From 0 to 10 inches, brown or dark grayish-brown heavy silt loam or silty clay loam. The material of this horizon, especially at the lower depth, is mixed or splotched with more yellowish-brown material which has been brought up from below, probably by deep tillage. It is of fine-granular structure. Although only a few lime concretions are in evidence, the soil will effervesce freely with hydrochloric acid. According to the soil and erosion survey, from 3 to 6 inches of the original surface soil of this particular soil has been lost by erosion since the area has been in cultivation. (2) From 10 to 20 inches, light-brown or yellowish-brown silty clay loam of granular structure, the granules being larger than in the layer above. The insides of the granules are lighter in color than the outsides. Lime concretions occur in this layer. There are, however, wide local variations in the depth at which the lime accumulations occur, and within a few feet the depth may vary from 15 to 30 inches. The layers or veins of lime may be either on a horizontal, an inclined, or, in a few places, on a vertical plane. (3) From 20 to 33 inches, yellowish-brown silty clay loam containing a large number of lime concretions. The material tends to approach a columnar structure, and blocks break and crush easily. (4) From 33 to 47 inches, brownish-yellow or buff-colored silty clay loam which is high in lime and similar in structure to the horizon above. (5) From 47 to 60 inches, material of similar color and structure as the above layer, but parts or splotches of this layer appear to be of finer texture. Lime concretions are less abundant. (6) From 60 to 72 inches, buff-colored material which is of slightly coarser texture than the layer above, being of a rather silty character. Some fine sand is found in many places at this depth. Lime is present but not in abundance as in the above horizon.

(7) The Vernon fine sandy loam, while red in color, must be classed with the Gray-Brown Podzolic soils. It is developed under low rainfall from red shales. The color is inherited from the shales. The profile is of markedly variable texture and is described by Mr. S. W. Phillips as follows: (1) From 0 to 3 inches, dark-brown fine sandy loam containing some organic matter; (2) from 3 to 10 inches, red fine sandy loam; (3) from 10 to 27 inches, compact red slightly sticky sandy clay; (4) from 27 to 58 inches, gritty heavy tough clay, with sandy clay in streaks or layers, showing some evidence of the alternating shales and sandstone which comprise the parent rock. The predominant color is red with some gray and pale-yellow layers of friable clay at a depth of about 50 inches. Some fragments of soft sandstone and shale are present in this layer.

(8A) The Kirvin fine sandy loam is a lateritic soil developed from heavy clays. It is red in color, and the textural variations within the profile are very marked according to the description of Mr. B. H. Hendrickson which is as follows: (1) From 0 to 12 inches, grayish-red loamy fine sand, including a thin organic surface layer; (2) from 12 to 24 inches, brick-red clay; (3) from 24 to 51 inches, brick-red clay mottled with gray; (4) from 51 to 63 inches, brick-red and light bluish-gray mottled very fine sandy clay with a seam of dark iron sandstone at a depth of 63 inches; and (5) from 63 to 75 inches, mainly yellow compacted fine sand.

(8B) The Nacogdoches fine sandy loam is a lateritic soil, very red in color and developed from much-weathered glauconitic limestone. It has a sharply variable profile according to the description of Mr. B. H. Hendrickson which is as follows: (1) From 0 to 8 inches, chocolate brownish-red gravelly

fine sandy loam; (2) from 8 to 18 inches, blood-red clay; (3) from 18 to 40 inches, red-yellow clay; (4) from 40 to 66 inches, red-yellow clay with some sand grains; and (5) from 66 to 72 inches, red-yellow sandy clay, rather heavy.

(9) The Houston black clay is a waxy soil derived from marl. It is a relatively undifferentiated profile of the Rendzina type. Calcium carbonate is present throughout the profile which is described by Mr. G. W. Musgrave as follows: (1) From 0 to 3 inches, black clay which is very plastic and sticky when wet but crumbles readily and is easily tilled when dry; (2) from 14 to 20 inches, grayish-black clay; (3) from 24 to 36 inches, gray clay; and (4) from 36 to 50 inches, yellowish-gray clay. The lighter-colored lower layers are more readily tilled when wet. The soil profile when saturated readily seals itself to penetration of surface waters.

(10) The Palouse silt loam is a Prairie soil developed on loessial material. Textural differences within the profile are slight, but the soil approximates the composition of the Chernozem. The profile, as sampled, was described by Mr. W. A. Rockie as follows: (1) From 0 to 20 inches, dark-brown silt loam or silty clay loam containing much organic matter; (2) from 20 to 30 inches, yellowish-brown or brown silty clay; (3) from 33 to 62 inches, yellowish-brown or brown silty clay; (4) from 62 to 75 inches, yellowish-brown or brown silty clay loam; and (5) from 75 to 84 inches, yellowish-brown or brown silt loam or silty clay loam.

In the reports on these Erosion Station soils cited above, their physical characteristics as well as their chemical composition, both of the whole soil and of the colloidal separate of each sample, are discussed at length especially from the standpoint of the relationship of these values to the tendency of the soils to erode under given conditions of slope and surface exposure. The physical measurements included, in addition to mechanical analyses, colloid by water vapor absorption, moisture equivalent, volume weight, settling volume, and a number of others in an effort to get at some physical or chemical characteristics of these soils closely associated with their natural tendency to erode which could be measured in the laboratory in a routine way.

The study of the trace element content of all the samples of these profiles by Slater et al [7] represents a bare beginning that was made at the time to see how significant the eroding away of the top soil was in removing the trace elements that had accumulated in it as a part of the natural process of developing a fertile soil. This phase of the problem has been under consideration for some time but no great amount of systematic work has been done on it. This possible tendency towards the accumulation of trace elements in the topsoil through plant action, *i.e.* the removal of these elements from the subsoil by the roots, their accumulation in the foliage of the plants—or in the whole plant in the case of annuals—and their subsequent return to the soil when the leaves fall or the whole plant dies, has been subsequently discussed by Goldschmidt [8]. An extension of this study in the interest of a more complete answer to the whole question would appear to be just as important as the part the trace elements play in the normal nutrition of plants, animals, and man.

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[7] *Loc. cit.*

[8] Goldschmidt, Dr. V. M.; The Principles of Distribution of Chemical Elements in Minerals and Rocks; Jour. Chem. Soc., 1937, pp. 655-673.

METHOD OF ANALYSIS

The spectrographic method of analysis was used exclusively in developing the principal data reported in this paper. However, the technique, including that of sample preparation, will not be discussed in detail in view of the excellent review of this whole procedure presented by Messrs. L. H. Rogers and R. C. Hughes in the immediately preceding paper, "Some Physical and Chemical Methods used in Determining the Trace Element Content of Soil, Plant, and Animal Materials" and by Messrs. R. A. Carrigan and L. H. Rogers in the paper that follows, "The Trace Element Content of Certain Florida Soils and Related Plant Materials."

It will suffice here to say, and to emphasize, that spectrographic data of the nature presented are not intended as precision determinations but only as indicative of the "order of magnitude" of the proportions of the elements present. To avoid misunderstanding as to accuracy, therefore, and also to retain a fairly legitimate basis for comparison, the data are commonly recorded as percentage "range" values. For instance, a range of .001-.005 per cent should be interpreted as meaning that the proportion of the element lies somewhere between .001 per cent and .005 per cent. In order to facilitate the tabulation and subsequent comparison of data of this nature, however, whole numbers will be used to represent these range values. This translation of range values to whole numbers is in accordance with the simple schedule attached to Table VI. The exploratory character of these values must especially be kept in mind when tentative averages are calculated to facilitate broad, general comparisons.

RESULTS

The detailed results of the spectrographic analyses of the Florida mineral soils are presented in Table V and those of the out-of-state soils in Table VI at the end of the paper. In view of the fact that all these analytical values are based on the ash of the original material, the results for the analyses of the peat and muck profiles from the Everglades are listed separately in Table IV. In the event it is desired to compare the trace element content of these soils with that of the mineral types, the comparatively low ash content of the organic types shall have to be taken into account.

In view of the highly heterogeneous nature of much of the data within a given soil type and the variability of the depth and thickness of the various horizons where the entire profile has been sampled, no general attempt at averaging these results will be undertaken except in the case of the five most important of the elements as we recognize and understand their relationships to plant and animal nutrition at the present time.

In the instance of the Florida soils, the trace element content and certain other phases of their mineral composition have been discussed in some detail in Florida Agricultural Experiment Station Bulletin 341 and there is no good reason for repeating it here. Notable among the findings reported was a good correlation between a higher trace element content and poor drainage; also in the apparently close association of calcium and strontium as well as iron and manganese.

TABLE I.—Average Copper, Manganese, Zinc, Boron, and Cobalt Content of the Topsoil and Subsoil of the Florida and Out-of-State Soils.[1]

Soils	Copper		Manganese		Zinc		Boron		Cobalt		No. Samples Averaged	
	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
A. Florida												
Norfolk	2	1	4	3	4	4	6	5	0	0	30	22
Orlando	2	1	6	5	6	5	6	5	0	0	4	3
Parkwood	4	1	8	7	4	5	5	6	0	0	10	5
Eustis	1	..	7	..	7	..	5	..	0	..	3	0
Scranton	4	1	2	2	5	5	5	5	0	0	2	2
Portsmouth	7	..	1	..	6	..	6	..	0	..	2	0
Lakewood	1	1	0	0	3	2	4	4	0	0	2	2
Blanton	1	1	6	0	2	1	3	2	0	0	1	1
Average[2]	3	1	4	3	5	4	5	4	0	0	54	35
B. Out-of-State												
Cecil	3	2	11	11	2	5	4	3	3	2	1	1
Muskingum	4	4	11	11	6	7	6	6	3	3	1	1
Clinton	3	4	11	11	4	8	3	6	3	4	1	1
Shelby	2	2	11	11	3	2	4	4	4	4	1	1
Marshall	2	4	11	11	3	2	4	4	3	4	1	1
Colby	4	4	11	11	4	2	4	4	3	2	1	1
Vernon	2	3	11	10	6	6	5	6	0	0	1	1
Kirvin	3	3	8	10	7	8	6	6	0	0	1	1
Nacogdoches	2	2	11	10	7	6	3	3	2	2	1	1
Houston	2	1	11	11	2	1	4	4	2	2	1	1
Palouse	4	4	11	11	4	4	6	4	4	3	1	1
Average[2]	3	3	11	11	4	5	4	4	2	2	11	11

[1] Presented as range numbers in the form reported in Tables V and VI where their relative values, in terms of approximate percentage ranges, are shown as a footnote under Table VI.

[2] It must be emphasized that averaging these range numbers, which merely represent the rough-estimate, percentage range values shown as a footnote to Table VI, in no wise improves their quantitative significance over and above that frankly discussed under method of analysis on page 76.

COPPER, MANGANESE, ZINC, BORON, AND COBALT

Of these five elements all but cobalt are recognized as necessary supplements to be applied under certain conditions in our fertilizer in proper amounts or as sprays to the foliage of a wide variety of plants for normal growth on a number of Florida soils. Up to the present time, little work has been done with cobalt in relation to plant growth insofar as its essentiality is concerned. It has been proven of very great importance in animal nutrition by workers in the Animal Industry Department of the Florida Agricultural Experiment Station, however, especially under certain range conditions, and on this account these range areas are known as "cobalt deficient." The general symptoms, as

recognized by practical cattlemen and experiment station workers vary but slightly from those of typical "Salt Sickness." However, the animal will not respond to the usual iron and copper treatment and usually dies unless it receives treatment with cobalt in due course from some source whether it be a proper change of range or the cobalt drenching bottle from the saddle-bag of a passing cowboy.

The comparative distribution of these five elements in Florida and "Out-of-State" soils is tentatively indicated in Table I where very general averages are presented for the topsoil and subsoil of each. Subsoil values are available for only six of the Florida soils. The depths of the "subsoils" for the out-of-state soils are indicated in Table V, the sample used for this purpose being the second depth tabulated in each instance.

Copper

Keeping in mind that the Florida soils involved in this study are from cultivated areas in every instance, it is apparent that the copper content of the topsoil compares favorably with that of the out-of-state soils though it is appreciably lower in the subsoil. In no horizon of any of the out-of-state soils was this element found to be entirely missing. It could not be detected, however, in several of the topsoil and subsoil samples in the Florida group. The "average" value for the Florida topsoils is, of course, greatly strengthened by the comparatively high content of the Parkwood, Scranton, and Portsmouth groups.

Manganese

In the instance of manganese, the content of the topsoil and subsoil of the out-of-state soils is much higher than the Florida soils, the high value for the element in this latter group carrying well down into the profile in every instance with the greatest weakness occurring in the Kirvin. Thus in eight of the eleven out-of-state profiles studied, the concentration is greater than 0.1 per cent in every horizon and well up toward this value in all the others. The distribution of this element among the samples of the lighter Florida soils is quite erratic though it is fairly satisfactory in those having higher quantities of organic matter or poorer conditions of drainage.

Zinc

The average content of this element shows surprisingly little difference as between the topsoil and subsoil of these two broadly different groups. It also carries down well in all of the out-of-state profiles, being lowest in the Houston black clay. The deeper subsoil of Kirvin fine sandy loam shows unusually high concentrations. It is rather surprising to note that this element was detected in every Florida sample tested, the lowest value in the topsoil being .0008-.003 per cent and the lowest in the subsoil being less than .001 per cent.

Boron

As in the case of zinc, there is little difference between the average content of boron in the top and subsoil samples of the Florida group in comparison with the out-of-state group. In a similar way, too, this

element carries down well into the profiles of the out-of-state soils, no sample showing less than .0008-.003 per cent.

Cobalt

Cobalt was not detected in any of the Florida mineral soils examined. While the sensitivity of the technique used for this element is low, still it was found in every horizon of eight of the eleven out-of-state profiles examined. It was not detected anywhere in the Kirvin profile or in the top two horizons of the Vernon or the two lowest horizons of the Nacogdoches. The importance of exceedingly small quantities of this element in animal (and in human?) nutrition makes it extremely important that a highly refined and exceedingly sensitive quantitative method be developed for it.

TITANIUM AND ZIRCONIUM

Titanium and zirconium occur very commonly in all the soils examined. In fact, every sample in both the Florida and out-of-state series showed both elements, most of them in quite high concentrations. Insofar as the analysis of the out-of-state soils for either element is concerned, zirconium showed the greatest variability in Houston clay, appearing in a concentration of less than .001 per cent in the lowest level of this profile. The lowest concentration of titanium and zirconium in any of the Florida topsoils was .008-.03 per cent in the case of a couple of the Norfolk samples for the former, and .0008-.003 per cent in the instance of four of the Norfolk and one of the Orlando samples for the latter element.

STRONTIUM, BARIUM, VANADIUM AND CHROMIUM

All four elements occur very consistently and in quite high concentrations in the out-of-state profiles. The exceptions were, for barium, in the lowest level of the Nacogdoches profile and, for strontium, in the lowest level of the Cecil and the Kirvin profiles, and in the second, third, and fifth levels of the Nacogdoches where it was not detected at all.

By comparison, the Florida soils are quite low and in most cases very variable in all four elements though Parkwood is quite consistent in showing a fairly good concentration of chromium and barium and especially of strontium in both the topsoils and subsoils. It is low in vanadium, however. The Orlando samples show the same general trend as the Parkwood in their content of these elements though the subsoil is much lower and in no Orlando sample was any vanadium, whatsoever, detected. Eustis and Scranton also show fair concentrations of these elements except vanadium where, in common with most of the Florida soils examined, it is either very low or not detected at all.

NICKEL AND SILVER

It is rather striking that nickel was found in every horizon of all out-of-state profiles examined in surprisingly consistent concentrations which range as high as .008-.03 per cent in the topsoil of the Marshall

silt loam and in the third horizon of the Shelby silt loam. Silver, on the other hand, was detected in only one horizon of each of four profiles, three of them being in concentrations less than .001 per cent.

The occurrence of nickel and silver in the Florida soils is highly erratic in both instances. Thus of the fifty-four topsoils examined, only ten contained nickel and one contained silver in detectable quantities; while of the thirty-five subsoils examined, three contained detectable quantities of nickel and two contained silver.

MOLYBDENUM AND LEAD

Although molybdenum was found in detectable quantities in eight of the eleven out-of-state profiles (in twenty-two of the fifty-two soil samples represented) and lead was found in quite consistent quantities in every profile and in all but four of the fifty-two soil samples examined, neither element was detected in any of the Florida mineral soils reported on in this paper. Molybdenum was not detected at any point in the Vernon, Houston, or Palouse profiles. The only out-of-state profile in which lead is not found at all levels sampled is the Nacogdoches where it occurs only in the fourth of the five horizons sampled.

EFFECT OF CULTIVATION AND RELATED PRACTICES ON THE TRACE ELEMENT CONTENT OF SOME FLORIDA SOILS

In the comparison that has been made of the trace element content of Florida soils to that of certain out-of-state soils, only samples from cultivated areas were used. This was largely because the out-of-state soils were taken from tilled areas, most of them having been farmed for a number of years. In view of the very great importance of the trace element content of our Florida soils, it would be very much worth while to inquire into the effect of cultivation and tillage, including routine treatment with artificial fertilizers, upon their composition from this standpoint.

This question has been opened up quite definitely in Bulletin 341 [9] of the Florida Agricultural Experiment Station referred to earlier and from which a few additional spectroanalyses will be drawn. In this bulletin it will be noted that analyses are reported on numerous cultivated top and subsoil samples from cultivated and uncultivated (virgin) areas falling in several different types. In the table below are listed the spectroanalyses for the topsoil and subsoil from a virgin and cultivated area of Orlando fine sand reported in the bulletin and the same for a Blanton fine sand that is not reported in the bulletin.

While a comparison of rather widely separated virgin and cultivated soils of two different soil types could hardly be regarded as conclusive from the standpoint of definitely indicating the effect of cultivation and related practices upon their trace element content, still there is indicated in the table a rather strong trend towards accumulation in both the topsoil and subsoil in the instance of several of the elements in which we are particularly interested. This tendency is especially marked in the

[9] *Loc. cit.*

TABLE II.—Trace Element Content of the Topsoil and Subsoil of a Virgin and Cultivated Orlando Fine Sand and of a Blanton Fine Sand.[1]

Element	Trace Element Content (Per Cent, as Range Number)							
	Orlando				Blanton			
	Topsoil		Subsoil		Topsoil		Subsoil	
	Virgin (1421)	Cult. (1478)	Virgin (1422)	Cult. (1479)	Virgin (1302)	Cult. (1508)	Virgin (1305)	Cult. (1509)
Zinc	2	5	2	3	2	6	6	2
Strontium	0	2	0	0	0	11	0	11
Barium	0	4	0	2	0	10	0	9
Chromium	0	1	0	1	1	5	2	6
Manganese	0	6	0	5	0	8	7	8
Zirconium	4	11	4	2	10	10	11	11
Titanium	6	11	6	11	11	11	11	11
Nickel	0	0	0	0	0	0	2	0
Copper	1	3	1	1	1	8	1	1
Boron	5	6	6	5	6	5	5	4

[1] Presented as range numbers in the form reported in Table V from which the values for the cultivated Orlando and Blanton soil and sub-soil are drawn. The values for the virgin topsoil and subsoil of both types are taken directly from Florida Bulletin No. 341. The relative values of these range numbers in terms of approximate percentage ranges are shown as a footnote under Table VI.

instance of copper, manganese, and zinc in the topsoil of both types. It is of especial interest to note that there is little difference between the boron content of the topsoil and subsoil under virgin and cultivated conditions for either soil since this is the only one of the four elements that has not come into rather common use on soil locations of the type sampled in these studies. On the basis of the limited number of tests made, it is, of course, difficult to explain the considerably higher content of manganese and zinc in the virgin subsoil of the Blanton in comparison with the topsoil.

Strontium, barium, chromium, zirconium, and titanium also show striking tendencies towards accumulation in both the topsoil and subsoil under cultivation, the principal exception being for zirconium in the Orlando subsoil, where the trend is reversed; and in the Blanton where the concentration is found to be quite high and the same under both conditions of cultivation but somewhat lower in the topsoil than in the subsoil. Titanium is unusually high in the Blanton, showing a concentration greater than 0.1 per cent in both the topsoil and subsoil under virgin as well as cultivated conditions.

Since an analysis of this nature is intended to show total quantities of the elements present, such figures, in any event, should not be interpreted to mean that even though there is a definite accumulation of trace elements in our Florida soils under such conditions, that they are necessarily available to the plant. This whole question is one which should be investigated further and most carefully, especially in connection with the well-known trend of phosphates to accumulate in our soils under what are regarded as standard conditions of treatment. Under such

conditions the availability of the accumulated trace elements that are known to be essential to the normal growth of plants should be examined with especial care.

In order to examine somewhat further this tendency of trace elements to accumulate in the soil following cultivation, the "Average" copper, manganese, zinc, and boron content of the topsoil of eleven virgin and thirty cultivated Norfolk soils are compared in Table III with eleven uncultivated or virgin areas of the same type; likewise four topsoil samples of virgin Orlando fine sand are compared with the same number from cultivated areas; and finally, the content of these elements in four virgin Parkwood soils are compared with those of ten cultivated Parkwood samples. While the values tabulated are prepared as tentative averages of the range numbers representing the percentage ranges given in Bulletin 341, the trend toward accumulation is very striking. The only exception is in the instance of the Parkwood values for zinc and boron and here they are found to be constant in both instances under the two conditions compared. The averages for the total phosphorus (P_2O_5) content of these same samples, as reported in Bulletin 341, show that the cultivated Norfolk contains three times as much of the element as the virgin soil, while the cultivated Orlando and Parkwood soils both contain more than twice as much as the equivalent samples taken from uncultivated areas.

TABLE III.—Further Indications of the Tendency of Trace Elements as Well as Phosphorus to Accumulate in Cultivated Soils.[1]

Element	Norfolk		Orlando		Parkwood	
	Virgin[2] (11)	Cult. (30)	Virgin (4)	Cult. (4)	Virgin (4)	Cult. (10)
Copper	1	2	1	2	1	4
Manganese	3	4	4	6	5	8
Zinc	2	4	3	6	4	4
Boron	5	6	4	6	5	5
Phosphoric[3] Acid (P_2O_5) (Per Cent)	.027	.081	.043	.095	0.110	0.258

[1] The spectroanalysis values were prepared as averages of the range numbers for both the virgin and cultivated soils (topsoils only), the former directly from Florida Bulletin No. 341 and the latter from Table V. The relative value of these range numbers, in terms of approximate percentage ranges, is shown as a footnote under Table VI.

[2] These figures indicate the number of individual samples averaged for each soil and condition of cultivation.

[3] Averages of the P_2O_5 content of the same soil samples upon which the average trace element contents are reported, as calculated from the original data in Fla. Bul. 341.

In view of what has been said regarding the possible relation of sheet erosion to the loss of particular concentrations of trace elements that have been concentrated in the topsoil by plant action and otherwise in the course of soil development, it is of interest to examine the trace element content of the out-of-state profiles from this standpoint. This can best be accomplished by studying the relative concentrations of the various elements in the topsoil in contrast with those at various levels in the subsoil. Such an examination could well be limited to the three top horizons in all profiles.

Approaching the question in this way it is found in the case of copper, manganese, zinc, and boron that only in a very few instances is there anything of a significant relationship indicated from this standpoint. Thus the copper concentration in the topsoil of Cecil and Houston appears slightly greater than in the immediate subsoil. The same is true of cobalt in Cecil, of zinc in Marshall and Colby, and of boron in Cecil and Palouse. On the whole, however, these variations in the direction of unusual accumulations in the topsoil or immediate subsoil are so slight as to be of rather doubtful significance not only in the above elements in which we have a particular interest but also in most of the others that were detected in these soils.

THE TRACE ELEMENT CONTENT OF A TYPICAL PEAT AND MUCK SOIL FROM FLORIDA

Inasmuch as the principal comparison of the trace element content of our Florida soils with certain out-of-state soils has been on the basis of mineral types, it is of interest to include the analysis of a complete profile of a sawgrass peat and a high grade muck. The profile description of the Everglades peat profile and the Okeechobee muck profile are outlined in some detail on pages 70-71 and their general location indicated on the map of Figure 1. Both profiles were sampled by preparing sufficiently large excavations to get down into them, all the way to the underlying rock, with the aid of pumps. It was thus possible to examine the stratification relationship of both profiles critically and sample the material accordingly. The results of spectroanalysis of these profiles are given in Table IV.

COPPER, MANGANESE, ZINC, COBALT, AND BORON

The copper, manganese, cobalt, and boron contents of the ash of these organic soils are quite consistent for each throughout both profiles and without particular reference to the specific character of the material in the various levels sampled. In general, the Everglades peat is slightly lower in manganese and higher in copper than the Okeechobee muck. The cobalt is low in all samples but was detected at each level except one quite low down in the Okeechobee muck. Boron showed the highest average concentrations throughout both profiles, having been found at every level examined and at no point in a lower concentration than .03-.08 pct. The occurrence of zinc is decidedly erratic with two, well separated samples in the Everglades peat profile showing an approximate concentration of .08-0.3 per cent without detection of the element at

TABLE IV.—Trace Element Content of Everglades Peat and Okeechobee Muck.[1]

Element	Everglades Peat (Lab. No. 16243)									Okeechobee Muck (Lab. No. 16245)								
	1 0-4″	*2* 4-15″	*3* 15-19″	*4* 19-26″	*5* 26-30″	*6* 30-40″	*7* 40-50″	*8* 50-74″	*9* 74-78″	*1* 0-9″	*2* 9-13″	*3* 13-26″	*4* 26-33″	*5* 33-58″	*6* 58-72″	*7* 72-77″	*8* 77-94″	*9* 94-104″
Strontium	10	11	11	11	11	11	11	11	9	1	1	1	8	9	11	11	10	1
Barium	9	9	10	10	9	10	9	9	7	5	1	1	8	8	8	6	6	4
Vanadium	0	0	5	0	0	0	0	4	2	6	6	4	2	4	1	1	1	1
Chromium	3	2	4	4	3	2	2	4	6	7	6	4	5	5	3	0	3	4
Manganese	9	3	5	5	5	5	5	6	5	8	6	5	9	8	10	9	6	6
Cobalt	3	1	2	2	1	2	2	2	2	2	1	1	3	2	2	2	0	1
Zirconium	0	0	6	0	10	0	0	9	11	11	10	10	0	0	0	0	9	11
Nickel	5	3	5	5	6	5	4	4	4	5	5	5	7	7	4	4	4	4
Silver	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Titanium	11	4	11	8	11	8	6	11	11	11	11	11	11	11	10	8	11	11
Copper	7	6	8	7	6	9	9	7	4	6	5	6	9	6	5	5	5	5
Molybdenum	2	2	2	2	2	2	0	2	1	2	3	2	3	2	3	2	2	1
Lead	2	0	1	0	1	0	2	2	1	1	1	0	1	1	1	1	1	1
Boron	10	9	9	8	8	9	10	10	10	10	10	10	10	8	10	10	10	10
Zinc	0	10	0	0	0	0	10	0	0	0	0	0	10	0	0	0	0	0
Loss on Ignition (Per Cent)	14	11	14	11	16	9	9	12	34	49	48	54	8	16	9	9	17	76

[1] Presented as range numbers in the form reported in Tables V and VI where their relative values, in terms of approximate percentage ranges, are shown as a footnote under Table VI.

any other point in this profile. Similarly, this element was detected at only one level in the Okeechobee muck profile where it was also present in the comparatively high concentration of .08-0.3 per cent. This peculiar trend in the occurrence of zinc may be due, in part at least, to definite interference by iron since the content of this latter element is quite high in both soils.

TITANIUM, STRONTIUM, BARIUM, ZIRCONIUM, NICKEL, AND CHROMIUM

Titanium, strontium, and barium, as well as nickel, were found in every level of both organic profiles in quite high concentrations with a few exceptions. Chromium was found at all levels in both profiles except at the 72″-77″ depth in the Okeechobee muck. The higher concentrations of strontium and barium seemed to occur at those levels in either profile that were higher in sawgrass components while the higher concentrations of titanium and zirconium seemed to favor the plastic sedimentary type of muck. The occurrence of nickel and chromium was more uniform throughout both profiles and seemed to be without particular reference to either type of component.

VANADIUM, MOLYBDENUM, AND LEAD

Vanadium occurred at every depth in the Okeechobee muck but at only three of the nine depths sampled in the Everglades peat which would tend to indicate a closer association with the plastic type of material occurring more commonly in the former profile. Both molybdenum and lead were quite well distributed through both the peat and muck profiles without any apparent reference to the physical nature of the materials, though lead occurred in quite low concentrations and was not detected in three levels of the peat profile and in one of the Okeechobee muck.

SUMMARY

The spectrographic analyses for 27 elements are reported for 54 cultivated soils from Florida, including the subsoils of more than half this number, and for 11 complete profiles from outside the State which include a total of 52 samples. These are used as the basis for a very preliminary comparison of the trace element content of Florida soils to those from outside the State that may be regarded by some as more "normal" in this respect. Supplementary analyses are included for Florida soils as a basis for discussing the effect of cultivation and related treatments on the trace element content of virgin soils as compared with cultivated soils.

In a general way the composition of the Florida soils compares quite favorably with that of the out-of-state soils in terms of three of the five trace elements in which we are particularly interested at the present time, namely, copper, zinc, and boron. Manganese was much higher in practically all of the out-of-state soils examined while cobalt was not detected in any of the Florida mineral soils that were included in this study.

Of the 27 elements for which all of the spectrographic plates were systematically examined, the following were not detected in any of the out-of-state soils: thallium, lithium, calcium, yttrium, tungsten, lanthanum, tin cadmium, beryllium, bismuth, antimony, and arsenic. To this list must be added cobalt, molybdenum, and lead for the Florida mineral soils.

In comparing cultivated and virgin Florida soils on the basis of the same series of types involved in the general study, Norfolk, Parkwood, Orlando, Scranton, Portsmouth, Eustis, Blanton, and Lakewood, quite a consistent tendency was indicated for improvement in the content of a number of trace elements with cultivation, notably copper, manganese, and zinc, as among those now known to be important to the growth of many plants.

Supplementary data were drawn from the same original source (Fla. Bul. 341) to show the strong tendency of these Florida soils to increase in their content of phosphoric acid with cultivation and normal management practices. Attention was called to the possible association of this increase in phosphoric acid with that of the trace elements. It was also pointed out and emphasized that the rough estimate values reported for the trace elements are totals and could in no sense of the word be interpreted as available to the plant, in the instance of the useful elements, until they had been so demonstrated by careful test.

The spectrographic analyses of a complete profile of an Everglades peat and of an Okeechobee muck are introduced for independent study and comparison with mineral soils. While the content of the ash of both soils is comparatively high for a number of elements, the ash content in most sections of these profiles is so low as to reduce these values to quite a low status if recalculated to the dry soil basis.

TABLE V.—Trace Element Content of Some Florida Soils.[1,2]

Soil Type	Surface Sample Number	Strontium Ts	Strontium Ss	Barium Ts	Barium Ss	Vanadium Ts	Vanadium Ss	Chromium Ts	Chromium Ss	Manganese Ts	Manganese Ss	Zirconium Ts	Zirconium Ss	Nickel Ts	Nickel Ss	Silver Ts	Silver Ss	Titanium Ts	Titanium Ss	Copper Ts	Copper Ss	Boron Ts	Boron Ss	Zinc Ts	Zinc Ss	Sub-Surface Number
Norfolk Sand and Fine Sand	1428	0	0	0	0	0	0	0	6	6	7	11	11	0	0	1	0	11	11	2	1	8	7	6	6	1429
	1432	0	0	2	0	0	0	2	0	6	6	8	11	0	0	0	0	11	11	1	1	7	7	6	6	1433
	1470	0	0	0	0	0	0	0	1	6	7	6	10	0	0	0	0	10	11	0	1	6	6	4	6	1471
	1482	0	0	2	2	0	0	0	1	7	6	11	2	0	0	0	0	11	11	1	1	6	6	2	4	1483
	1472	0	0	2	2	0	0	0	2	6	6	8	6	0	0	0	0	10	10	1	1	6	6	3	2	1473
	1525	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	6	6	1	0	6	5	4	2	1526
	1527	0	0	2	0	0	0	0	0	6	0	4	8	0	0	0	0	10	10	1	1	5	6	4	4	1528
	1415	0		2		0		0		6		6		0		0		10		1		8		2		
	1416	0		2		0		0		6		2		0		0		10		1		6		4		
	1417	0		2		0		2		6		10		0		0		11		1		6		6		
	1419	0		0		0		2		6		2		0		0		10		0		6		7		
	1420	0	0	4	0	0	0	2	0	6	5	6	10	0	0	0	0	11	11	2	0	6	7	5	2	1418
	1426	0	0	2	0	0	0	2	0	6	0	11	10	0	0	0	0	11	11	1	1	7	7	6	6	1427
	1434	0	0	0	0	0	0	0	2	0	2	10	11	0	0	0	0	11	11	1	1	6	5	2	1	1435
	1469	0	0	0	0	0	0	0	0	5	2	6	2	0	0	0	0	10	10	8	1	6	6	7	2	1457
	1742	6	2	6	2	0	0	2	2	6	4	11	10	0	0	0	0	11	11	5	2	6	5	4	2	1759
	1743	0	0	2	2	0	0	1	0	4	2	11	8	0	0	0	0	11	11	2	1	6	4	2	2	1758
	1744	6	2	4	2	0	0	0	2	4	4	11	10	0	0	0	0	11	11	4	1	6	6	3	4	1773
	1752	4	0	4	0	0	0	0	0	6	2	8	6	0	0	0	0	10	10	6	1	2	2	2	2	1761
	1766	6	6	6	2	0	0	3	4	6	6	10	11	0	0	0	0	11	11	6	3	6	4	4	5	1748
	1767	6	0	6	2	0	0	0	2	4	3	11	11	0	0	0	0	8	11	2	1	4	5	2	4	1741
	1157	0		2		0		1		0		2		0		0		6		1		6		7		
	1161	0		2		0		0		0		8		0		0		10		1		6		4		
	1162	6		4		0		2		4		11		4		0		10		3		3		2		
	1166	0		2		0		0		0		8		0		0		8		1		5		4		
	1498	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	10	10	1	0	6	6	2	2	1499
	1500	6	0	2	0	0	0	0	0	0	0	10	8	0	0	0	0	10	11	1	1	6	6	4	4	1501
	1502	0	0	0	0	0	0	0	0	0	0	6	6	0	0	0	0	10	11	0	1	6	4	4	4	1503
	2238	10	6	2	2	0	0	2	2	6	4	11	10	0	0	0	0	11	11	3	2	4	4	2	4	2239
	2250	6	0	4	2	2	2	4	6	8	7	11	10	4	2	0	0	11	11	6	4	6	6	6	6	2251

[1] All plates were examined for the following elements but they were not detected in any sample reported in this table: thallium, lithium, caesium, yttrium, tungsten, lanthanum, tin, cadmium, beryllium, bismuth, antimony, arsenic, cobalt, molybdenum and lead.

[2] Reported as range numbers, for the relative value of which, in terms of the approximate percentage ranges, see footnote under Table VI.

(Continued)

TABLE V.—Trace Element Content of Some Florida Soils.—*Continued.*

Soil Type	Surface Sample Number	Strontium Ts	Strontium Ss	Barium Ts	Barium Ss	Vanadium Ts	Vanadium Ss	Chromium Ts	Chromium Ss	Manganese Ts	Manganese Ss	Zirconium Ts	Zirconium Ss	Nickel Ts	Nickel Ss	Silver Ts	Silver Ss	Titanium Ts	Titanium Ss	Copper Ts	Copper Ss	Boron Ts	Boron Ss	Zinc Ts	Zinc Ss	Sub-Surface Number
Orlando	1425	6		2		0		7		5		2		0		0		10		1		7		6		
Fine	1478	2	0	4	2	0	0	1	1	6	5	11	2	0	0	0	0	11	11	3	1	6	5	5	3	1479
Sand	1480	0	0	3	2	0	0	0	0	4	2	10	2	0	0	0	0	10	8	2	0	6	4	6	6	1481
	2262	11	8	7	6	0	0	6	4	8	7	11	10	2	2	0	0	11	11	2	1	6	6	6	5	2263
Parkwood	1506	11	11	10	10	2	0	7	6	11	9	11	11	0	0	0	0	11	11	2	1	5	6	6	5	1506
Fine	1296	9	11	4	8	0	0	2	5	8	7	8	11	0	0	0	1	10	11	2	2	4	6	4	6	1320
Sand	1298	10		2		0		6		8		11		2		0		11		4		3		2		
and	1307	10	10	5	5	2	2	6	6	7	7	10	11	0	2	0	0	11	11	0	2	6	6	6	4	1319
Fine	1321	10	8	8	4	0	2	6	6	7	7	11	11	0	0	0	0	11	11	6	1	6	7	6	6	1308
Sandy	1322	10	10	6	6	0	0	4	2	8	7	8	11	0	0	0	0	11	11	8	1	6	6	2	2	1318
Loam	1339	11		6		0		6		6		10		0		0		10		1		5		2		
	1340	10		5		0		2		10		11		1		0		11		10		4		4		
	1342	11		8		2		6		6		8		2		0		11		6		6		6		
	1344	9		6		2		4		7		10		1		0		11		4		5		5		
Eustis	1194	6		4		2		4		7		11		2		0		11		1		5		8		
Fine	1195	5		3		0		2		7		11		2		0		11		1		6		6		
Sand	1198	10		5		2		5		8		11		2		0		11		2		5		6		
Scranton	1901	6	8	2	6	0	0	3	4	2	2	11	11	0	0	0	0	11	11	2	1	6	6	6	5	1902
Fine Sand	1903	7	7	4	4	0	0	3	4	2	2	10	11	0	0	0	0	11	11	7	1	4	5	5	5	1904
Portsmouth	1158	2		2		0		2		0		11		0		0		11		8		6		6		
Fine Sand	1159	2		2		0		1		2		10		0		0		11		6		6		6		
Lakewood	1514	2	0	2	0	0	0	0	0	0	0	8	4	0	0	0	1	6	6	2	1	5	5	4	2	1515
Fine Sand	1516	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0	10	2	1	0	4	4	2	2	1517
Blanton Fine Sand	1754	6	0	4	0	0	0	2	0	6	0	10	2	0	0	0	0	10	6	1	1	3	2	2	1	1757

See p. 87 for footnotes.

TABLE VI.—Trace Element Content of Some Out of State Soils.[1] [2]

	Soil	Depth	Stron-tium	Bar-ium	Vana-dium	Chro-mium	Man-ganese	Cobalt	Zirco-nium	Nickel	Silver	Tita-nium	Cop-per	Molyb-denum	Lead	Boron	Zinc	Lab. No.
1	Cecil	0"- 6"	9	10	8	8	11	3	11	5	0	11	3	0	2	4	2	2716
	Sandy	6"-32"	2	8	8	8	11	2	11	4	0	11	2	1	2	3	5	2717
	Loam	32"-60"	0	8	9	8	11	2	11	4	0	11	2	1	2	3	4	2718
2		0"- 7"	11	11	10	8	11	3	11	3	0	11	4	1	2	6	6	2754
	Muskingum	8"-13"	11	11	10	9	11	3	11	4	0	11	4	2	3	6	7	2755
	Silt	14"-24"	11	11	11	11	11	3	11	4	0	11	4	2	4	6	6	2756
	Loam	25"-46"	11	11	10	9	11	3	11	3	0	11	4	2	2	6	6	2757
		47"-72"	11	11	10	10	11	4	11	4	0	11	4	1	4	8	8	2758

[1] All plates were examined for the following elements but they were not detected: Thallium, lithium, caesium, yttrium, tungsten, lanthanum, tin, cadmium, beryllium, bismuth, antimony, and arsenic.

[2] The percentage ranges represented by the range numbers used in Tables I-VI to display the approximate content of the various trace elements detected in the soils under examination are listed as follows:

Range No.	*Concentration Range (Percent)*
0	Not detected
1	Less than .001
2	.0008 - .003
3	.001 - .005
4	.003 - .008
5	.005 - .01
6	.008 - .03
7	.01 - .05
8	.03 - .08
9	.05 - .1
10	.08 - .3
11	Greater than 0.1

(Continued)

TABLE VI.—Trace Element Content of Some Out of State Soils.—*Continued.*

	Soil	Depth	Stron-tium	Bar-ium	Vana-dium	Chro-mium	Man-ganese	Cobalt	Zirco-nium	Nickel	Silver	Tita-nium	Cop-per	Molyb-denum	Lead	Boron	Zinc	Lab. No.
3		0″- 8″	11	11	9	9	11	3	11	3	0	11	3	0	2	3	4	2733
	Clinton	8″-20″	11	11	9	9	11	4	11	4	0	11	4	0	3	6	8	2734
	Silt	20″-32″	11	11	9	8	11	3	11	4	1	11	2	1	2	6	6	2735
	Loam	32″-44″	11	10	8	8	11	3	11	4	0	11	4	1	4	7	10	2736
		44″-66″	6	6	2	6	11	1	11	4	0	11	4	0	3	5	9	2737
4		0″- 7″	11	11	11	10	11	4	11	4	0	11	2	1	4	4	3	2723
	Shelby	8″-12″	11	11	10	10	11	4	11	4	0	11	2	2	4	4	2	2724
	Silt	12″-20″	11	11	10	9	11	4	11	6	1	11	6	2	6	4	4	2725
	Loam	20″-24″	11	11	10	10	11	3	11	5	0	11	4	1	6	6	7	2726
		24″-48″	11	11	8	8	11	3	11	5	0	11	2	2	6	6	5	2727
		60″-84″	11	11	10	8	11	3	11	4	0	11	3	0	6	6	2	2728
5		0″-13″	11	11	11	10	11	3	11	6	0	11	2	0	2	4	3	2719
	Marshall	13″-24″	11	11	10	9	11	4	11	5	0	11	4	2	3	4	2	2720
	Silt	24″-45″	11	11	10	9	11	4	11	4	0	11	2	2	4	5	2	2721
	Loam	45″-71″	11	11	9	9	11	2	11	4	2	11	2	0	4	5	2	2722
6		0″-10″	11	11	10	9	11	3	11	4	0	11	4	1	6	4	4	2738
	Colby	10″-20″	11	11	10	9	11	2	11	4	0	11	4	0	4	4	2	2739
	Silty	20″-33″	11	11	9	9	11	3	11	4	0	11	4	0	6	3	2	2740
	Clay	33″-47″	11	11	9	9	11	2	11	3	0	11	2	0	4	3	2	2741
	Loam	47″-60″	11	11	10	9	11	3	11	4	0	11	3	0	4	5	2	2742
		60″-72″	11	11	10	9	11	3	11	4	0	11	2	0	4	3	2	2743
7	Vernon	0″- 3″	6	6	5	8	11	0	11	2	0	11	2	0	2	5	6	2759
	Fine	3″-10″	6	6	2	6	10	0	11	4	1	11	3	0	2	6	6	2760
	Sandy	10″-27″	11	11	6	8	11	3	11	4	0	11	4	0	3	7	6	2761
	Loam	27″-58″	11	11	7	8	10	3	11	5	0	11	5	0	4	6	7	2762

See p. 89 for footnotes.

TABLE VI.—Trace Element Content of Some Out of State Soils.—*Continued.*

Soil	Depth	Stron-tium	Bar-ium	Vana-dium	Chro-mium	Man-ganese	Cobalt	Zirco-nium	Nickel	Silver	Tita-nium	Cop-per	Molyb-denum	Lead	Boron	Zinc	Lab. No.
8A	0″-12″	6	6	2	6	8	0	11	2	0	11	3	0	2	6	7	2763
Kirvin	12″-24″	10	9	10	10	10	0	11	5	0	11	3	2	2	6	8	2764
Fine	24″-51″	8	9	9	9	8	0	11	4	0	11	1	1	2	6	8	2765
Sandy	51″-63″	6	9	7	8	6	0	11	2	0	11	2	0	2	6	11	2766
Loam	63″-75″	0	6	2	4	1	0	10	1	0	11	1	0	1	4	11	2767
8B	0″- 8″	6	8	10	8	11	2	11	3	0	11	2	2	0	3	7	2749
Nacogdoches	8″-18″	0	2	10	7	10	2	11	4	0	11	2	2	0	3	6	2750
Fine	18″-40″	0	1	10	7	6	1	11	4	0	11	2	2	0	3	7	2751
Sandy	40″-66″	8	6	10	7	10	0	11	3	0	11	2	0	2	3	7	2752
Loam	66″-72″	0	0	9	7	6	0	11	4	0	10	2	0	0	3	7	2753
9	0″- 3″	11	7	7	7	11	2	9	3	0	11	2	0	2	4	2	2729
Houston	14″-20″	11	7	6	7	11	2	8	3	0	11	1	0	2	4	1	2730
Black	24″-36″	11	9	6	8	11	2	6	4	0	10	1	0	2	2	2	2731
Clay	36″-50″	11	8	5	8	11	2	1	3	0	10	1	0	2	4	1	2732
10	0″-20″	11	11	10	10	11	4	11	4	0	11	4	0	4	6	4	2744
Palouse	20″-33″	11	11	10	9	11	3	11	4	0	11	4	0	3	4	4	2745
Silt	33″-62″	11	11	10	10	11	4	11	4	0	11	4	0	2	4	2	2746
Loam	62″-75″	11	11	10	10	11	4	11	4	0	11	4	0	2	6	5	2747
	75″-84″	11	11	11	11	11	3	11	4	0	11	4	0	4	4	2	2748

See p. 89 for footnotes.

THE TRACE ELEMENT CONTENT OF CERTAIN FLORIDA SOILS AND RELATED PLANT MATERIALS

R. A. Carrigan and L. H. Rogers*

The importance of the so-called "trace" or "minor" elements for Florida agriculture is now widely recognized. Though much valuable information relating to the trace element nutrition of Florida crops has been accumulated in recent years, the systematic study of the trace element composition of the soils and of the plant and animal crops of the state, as a means of elucidating the nutritional relationships involved, is still in the exploratory stage. In a program of this kind, including work with various crops, preliminary surveys of the qualitative composition of numerous materials must be made, as a basis for planning more comprehensive quantitative studies. The present paper reports survey analyses for trace elements in a group of Florida soils used for citrus production together with the corresponding data for samples of fruit tissues from orange trees growing on the soils.

Detailed knowledge of the trace element content of various materials is essential to establishing basic facts regarding conditions regulating the supply of these elements to plants and animals, especially as interrelationships with the soil are involved. Data of this kind are needed for evaluating the nutritional quality of all kinds of crops used as food for animals and man, as well as for determining the normal physiological requirements for trace elements of both plants and animals. Questions as to what might constitute normal, sub-normal, or excessive concentrations of trace elements in plant or animal parts remain, to a large extent, unanswered. In soil areas producing low yields, even though the usual physiological symptoms are not recognizable in the crops grown, it is natural to expect that mineral deficiencies may exist. Correlations between mineral content of soils and plant and animal tissues need to be worked out in a number of such cases to serve as a guide to practical experimental approaches to these problems. These examples of the possible use of trace element analyses are given merely as illustrations of the potentialities of this mode of attack. Answers to these and many related questions will be necessary to the development of the well-rounded body of information requisite for a fully satisfactory understanding of the proper methods of managing any given crop. The trace element question is, of course, only one aspect of the problem as a whole; but in Florida it is undoubtedly of outstanding importance.

In the study of a phenomenon as complex as that of the growth of living organisms, the effects of a number of variables must be investigated. These variables need to be considered in regard to the effect of each by itself on the organism, and also in their interrelations with

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each other. Thus, any given observation, such as an analysis for a mineral constituent, is of most value when accompanied by as many other related observations as possible. It is desirable, therefore, that analyses of soils be made in conjunction with those of associated plant materials. Six of the soil analyses reported here have appeared in a bulletin by Rogers et al (24). When these soil samples were taken, samples of oranges were also obtained from trees growing at the respective sampling locations, in order to be able to secure analyses of related plant materials. The oranges were Valencias in all cases except those taken on the peat soil in Broward County, which were of the Lue Gim Gong variety.

PREVIOUS WORK

Previous work on trace element content of soils need not be cited extensively since adequate summarizations of the literature are already available (27, 30, 32). Studies on trace elements in Florida soils have been made by Bryan and Becker (5), Peech (21), and Rogers et al (24). Jones, Gall, and Barnette (16) have studied the reaction of zinc sulfate with the soil and Peech (22) has investigated the effect of pH on availability of zinc and copper.

Very few studies of trace elements in oranges have been reported in the literature. Most of this work has been confined to the elements boron (8, 20, 25), copper (7, 11, 12, 13, 15, 17, 29), manganese (1, 4, 7, 9, 10, 11, 12, 14, 18, 19, 26, 29), and zinc (2, 11,). Aluminum has been determined by several investigators (3, 9, 10, 11, 28, 31). Roberts and Gaddum (23) have reported analyses for 19 trace elements in citrus juices.

SAMPLING PROCEDURE AND SAMPLE PREPARATION

Samples of the surface soil were taken to a depth of six inches, the composite sample from each location being made up from four borings. The mixed soil, after drying in an oven at 110°C., was screened through an aluminum sieve having round holes of two millimeters diameter. After further mixing and quartering, portions were ignited at 450°C. in silica dishes and ground in an automatic agate mortar to effect thorough mixing as well as to pulverize the coarser particles. Further details are given in the publication referred to above (24).

The fruit sample from each location included 24 oranges. All fruit were washed with distilled water and dissected with a stainless steel knife coated with paraffin wax to avoid metallic contamination as far as possible. The fruit tissues analyzed were the outer peel, inner peel, pulp and seed. The peels and seeds were dried in an electric oven. Unfortunately, the temperature of drying could not be controlled since adequate thermostatic equipment was not available when the work was done. However, uncertainties in dry matter percentages due to this factor are probably not important in comparison with variations in the spectrographic estimations. The pulp, including the juice, was evaporated and charred in large porcelain dishes. All materials were ashed at 450°C. Every reasonable effort was made to prevent metallic contamination in sample preparation and storage. During ashing, the samples were contained in silica dishes. The entire quantity of each tissue from

each sample of 24 oranges was carried through to the ash stage. Prior to the analysis, each sample of ash was mixed thoroughly by grinding by hand in an agate mortar.

METHOD OF ANALYSIS

All analyses were done spectrographically. Samples of approximately 10 milligrams of the ashed materials were volatilized completely in an electric arc between graphite electrodes, with an arc current of 9 to 10 amperes D. C. The electrodes were of the highest purity obtainable and frequent blanks were run as a check against possible electrode impurities. The spectrograph used was of the Littrow type with linear dispersion of about 30 inches between 2250 and 5500 A. For wavelengths greater than 3800 A., a glass prism was used in the spectrograph; below 3800 A., a quartz prism was used. Separate exposures were made on a small quartz Cornu type spectrograph in order to make use of the sensitive zinc line at 2138 A.

The analytical procedure was designed to reveal qualitative trace element composition with only rough estimation of the percentage concentration of each element identified. The survey nature of the study did not warrant the employment of actual quantitative analytical methods.

TABLE I.—Range Numbers and Corresponding Percentage Ranges.

Range No.	Percentage Range
0	Not Found
1	Less than 0.001
2	0.0008 - 0.003
3	0.001 - 0.005
4	0.003 - 0.008
5	0.005 - 0 01
6	0.008 - 0.03
7	0.01 - 0.05
8	0.03 - 0.08
9	0.05 - 0.1
10	0 08 - 0.3
11	Greater than 0.1

To avoid possible misinterpretation of the precision, the data are not reported in terms of definite percentage values. Instead, the approximate percentage concentration of any given element in a sample is indicated by the use of one of a series of "range numbers" which are defined in terms of percentage ranges as shown in Table I. Thus, when an element is reported to occur in a concentration identified by range number 7, it is estimated to be present at a concentration between 0.01 per cent and 0.05 per cent, by weight, in the ashed material.

Even with the use of the range numbers for reporting estimated concentrations, there is a possibility of misunderstanding of the precision attained, owing to the differentiation of the analytical values into as many

as twelve ranges. In order for two samples to show an unmistakable difference in the content of a given element by the method of observation employed, the absolute concentrations of the element in the two samples would have to differ by something like a factor of three. Definite significance should not, therefore, be attributed to a variation between any pair of samples unless the range assignments for the two samples correspond to numbers differing by 2, or preferably 3 or more, in the "Range No." column above. Nevertheless, it has seemed best to retain the twelve ranges in order to avoid ambiguity in classifying samples which would be borderline cases if a lesser number of ranges were used. Non-detection of an element, indicated in the table by the notation 0, does not necessarily mean that the element is completely absent from the sample, but only that if it is present it occurs in a concentration below the lower limit of detectability of the method. The approximate value of this limit is: for silver, cobalt, chromium, copper and nickel, 0.0001 per cent; for barium, beryllium, boron, manganese, molybdenum, lead, tin, strontium, titanium, vanadium, and zinc, 0.001 per cent; for zirconium, bismuth, cadmium, lanthanum, antimony, thallium, and yttrium, 0.01 per cent; for arsenic, caesium, lithium, and tungsten, 0.1 per cent.

Rough estimations were facilitated by photographing spectra of samples adjacent to spectra of standard materials prepared synthetically. In this way it was possible to make direct visual comparisons of line intensities in the samples with the intensities of corresponding lines in reference materials of known trace element composition. The synthetic standards were made to correspond approximately to the major element composition of the materials under test. Since only rough estimations were sought, possible effects of variations in the major element composition of the samples on spectral line intensities were not considered. At least two exposures were made for each sample.

ANALYTICAL RESULTS

The detailed data are presented in Table II. Soil pH values are included since these are of interest in connection with the availability of certain of the trace elements. Loss on ignition is reported on the basis of the oven-dried soil.

The analytical data for both soils and plant tissues are reported on the basis of the ashed material. In the case of the peat, trace element concentrations in the whole soil would be, therefore, only about one-third as great as are reported on the ash basis in the table.

Data for zirconium are not reported in the table. This element was not detected in any of the plant samples nor in the marl soil. It occurred in all the other soils in concentrations indicated by range numbers as follows: in samples 1339 (Parkwood), 1434 (Norfolk), 1508 (Blanton), and 1754 (Blanton), range number 10; in samples 1322 (Parkwood), 1731 (Peat), and 1752 (Norfolk), range number 8; in sample 1498 (Norfolk), range number 5.

Vanadium, detected in none of the plant tissues, was found only in the peat soil in a concentration estimated to fall in range 2.

TABLE II.—Analytical Data.
(See Table I for values used in presenting trace element values.)

Sample No. Surface Soil	Soil Type	County	Surface Soil		Dry Matter in Fruit Tissues			Ash in Fruit Tissues				Aluminum				
			Loss on Ignition per cent	pH	per cent of fresh weight			per cent of dry matter			per cent of fresh material					
					O.P.	I.P.	Sd	O.P.	I.P.	Sd	P	S[1]	O.P.[2]	I.P.[3]	P[4]	Sd[5]
1434	Norfolk Fine Sand	Lake	2.2	5.63	30.7	34.0	43.8	4.1	2.0	3.1	0.40	10	6	10	10	10
1752	Norfolk Sand	Polk	3.6	5.32	22 5	27.5	50.3	5 3	2.9	2.9	0.31	11	6	8	4	6
1498	Norfolk Fine Sand	Pinellas	1.8	5.32	28 3	30.3	47.2	4 5	2.3	3.0	0.53	11	6	6	9	6
1508	Blanton Fine Sand	Manatee	9.5		29.7	29.2	41.9	3.9	2.0	3.7	0.44	11	5	1	4	6
1754	Blanton Fine Sand	DeSoto	3.0	5.58	35.3	37.0	47.5	4.6	2.8	3.4	0.56	11	6	7	6	10
1322	Parkwood Sandy Loam	Indian River	8.5		35.0	37.9	38.9	2.7	2.2	4.1	0.35	11	2	4	6	8
1339	Parkwood Sandy Loam	St. Lucie	6 9	8.30	29.4	29.2	50.0	5.1	3.8	3.2	0.42	11	6	4	2	9
1721	Perrine Marl	Dade	9.0		36.6	38.7	45.3	5.1	3.0	3.9	0.45	11	8	3	8	9
1731	Shallow Peat	Broward	65.0		31.4	32.8	48.8	3 9	3.7	3.2	0.43	11	2	1	6	10
Mean					31.0	33.0	46.0	4.4	2.7	3.4	0.43	11	5*			

[1] "S" denotes surface soil. [2] "O.P." denotes outer peel. [3] "I.P." denotes inner peel. [4] "P" denotes pulp. [5] "Sd" denotes seed.
* Denotes a qualified mean value obtained after omitting one or more exceptional values.

(Continued)

TABLE II.—Analytical Data.—*Continued.*

Sample No. Surface Soil	Soil Type	Barium					Boron					Chromium					Copper				
		S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd
1434	Norfolk Fine Sand	0	9	8	5	9	6	8	10	8	10	0	0	0	0	0	1	4	2	3	7
1752	Norfolk Sand	4	4	8	2	2	2	8	9	8	8	0	0	0	0	0	6	6	6	3	6
1498	Norfolk Fine Sand	0	9	10	2	3	6	7	9	6	8	0	0	0	1	0	1	2	6	5	7
1508	Blanton Fine Sand	10	1	2	1	1	5	8	9	6	6	5	0	0	1	0	8	4	4	6	6
1754	Blanton Fine Sand	4	8	9	1	6	3	7	9	5	8	2	0	0	1	0	1	4	6	5	6
1322	Parkwood Sandy Loam	6	5	7	2	6	6	8	8	6	8	4	0	0	1	0	8	5	6	7	8
1339	Parkwood Sandy Loam	6	7	6	1	7	5	8	8	6	8	6	2	0	0	0	1	6	7	6	8
1721	Perrine Marl	8	1	2	1	1	2	8	9	7	8	8	1	0	1	0	1	6	6	4	7
1731	Shallow Peat	10	6	7	1	6	6	9	9	7	7	7	0	0	1	0	6	6	7	6	8
Mean								8	9	7	8			0	1*	0		5	6	6	7

See p. 96 for footnotes.

TABLE II.—Analytical Data.—*Continued.*

Sample No. Surface Soil	Soil Type	Lead					Manganese					Molybdenum					Nickel				
		S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd
1434	Norfolk Fine Sand	0	0	2	1	4	0	6	4	4	8	0	0	0	0	0	0	0	0	0	2
1752	Norfolk Sand	0	0	0	0	0	6	6	6	4	8	0	0	0	0	0	0	0	0	0	2
1498	Norfolk Fine Sand	0	0	0	1	0	0	7	7	4	8	0	0	0	0	1	0	0	0	0	2
1508	Blanton Fine Sand	0	0	0	2	1	8	7	8	6	8	0	0	0	0	1	0	0	0	2	2
1754	Blanton Fine Sand	0	0	1	0	0	6	7	8	6	9	0	0	0	0	0	0	0	0	1	3
1322	Parkwood Sandy Loam	0	0	0	2	0	8	2	3	5	6	0	0	0	0	2	0	0	0	0	0
1339	Parkwood Sandy Loam	0	0	0	0	0	6	4	4	3	7	0	0	0	0	0	0	0	0	0	0
1721	Perrine Marl	0	1	1	1	0	11	6	6	6	7	0	0	0	0	1	3	0	0	0	0
1731	Shallow Peat	0	1	2	2	0	11	8	6	5	8	0	0	0	0	2	4	0	0	0	0
Mean		0						7	7	5	8	0	0	0	0			0	0		

See p. 96 for footnotes.

TABLE II.—Analytical Data.—*Continued.*

Sample No. Surface Soil	Soil Type	Silver					Strontium					Titanium					Zinc				
		S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd	S	O.P.	I.P.	P	Sd
1434	Norfolk Fine Sand	0	0	0	0	0	0	10	8	8	8	11	0	0	1	0	2	6	6	6	10
1752	Norfolk Sand	0	0	0	0	0	4	8	10	6	2	10	0	0	0	0	2	3	6	6	8
1498	Norfolk Fine Sand	0	0	0	0	0	0	9	8	1	1	10	1	0	0	0	2	6	6	5	10
1508	Blanton Fine Sand	0	0	0	0	0	11	11	11	10	6	11	0	0	0	0	6	6	6	6	8
1754	Blanton Fine Sand	0	0	0	0	0	6	10	10	6	6	10	0	0	0	0	2	4	6	4	8
1322	Parkwood Sandy Loam	0	0	0	1	0	10	9	10	9	10	11	0	0	0	0	2	5	4	7	8
1339	Parkwood Sandy Loam	0	0	0	0	0	11	11	11	11	11	10	0	0	0	0	2	4	6	6	6
1721	Perrine Marl	0	1	1	1	0	11	11	11	7	7	6	0	0	1	0	2	6	5	9	9
1731	Shallow Peat	0	0	0	0	0	11	11	11	11	10	8	0	0	0	0	4	6	6	6	7
Mean		0				0								0		0	2*	5	6	6*	8

See p. 96 for footnotes.

In a general way, the elements found in the plant materials and those detected in the soils tended to be the same. Thus, aluminum, boron, copper, and zinc were found in all of the soils and in all of the plant tissues. The same can be said of manganese, strontium, and barium if the soils from two of the Norfolk locations are excluded. Chromium and nickel were found irregularly in both soils and plants.

Exceptions to the general rule were lead, molybdenum, silver, titanium, and zirconium. The first three were detected in some of the plant samples but in none of the soils, although lead and silver have been found in other mineral soils from Florida (24) and molybdenum is apparently of common occurrence in Everglades soils (6). Zirconium was found exclusively, and titanium almost exclusively in the soils although zirconium, as well as titanium, has been detected in citrus juices by Roberts and Gaddum (23).

Elements sought but detected in neither the plant tissues nor in the soils were: antimony, arsenic, beryllium, bismuth, cadmium, caesium, cobalt, lanthanum, lithium, thallium, tin, tungsten, and yttrium. Although tin was not found in this study, its presence has been reported in certain citrus juices by Roberts and Gaddum (23). Attention is again called to the fact that these elements could have been present in concentrations below the limit of sensitivity of the technique used. For example, it seems not unlikely that lithium might have been detected in many of the samples if the range of spectrum photographed had been extended to include the more sensitive lithium line at 6707 A. Moreover, certain of these elements might possibly have been lost in the ignition procedure, for example arsenic and antimony.

The brief comments following summarize the data with respect to the individual elements. While it is recognized that it would be desirable to base comparisons between tissues on the dry matter, this was not done since facilities for obtaining true ash content of the dry matter of the pulp were not available when the work was done. All such comparisons are therefore made on the ash basis.

Aluminum occurred in all of the soils and in all of the plant samples. Its concentration exceeded 0.1 per cent in all but one of the soils but was definitely below this level in most of the plant ashes. The erratic behavior of aluminum under the conditions of the technique used makes detailed comparisons hazardous; there is, however, a suggestion in the data that aluminum, under some conditions, may tend to be higher in the seeds than in the other plant tissues analyzed.

Barium was detected in all of the samples except two of the Norfolk soils. The content of barium in both the soils and plant materials was quite variable. The most noticeable uniformity in the distribution of this element appears to be in its tendency to be consistently low in the pulp.

Boron occurred in all of the samples and showed a pronounced tendency to be higher in the plant ashes than in the soils.

Chromium was detected in several of the plant tissues and in all of the soils except those of the Norfolk series. It occurred in all but three of the pulp samples, two of the exceptions being associated with soils in

which chromium was not detected. Except for the pulp samples, the only plant tissues showing detectable chromium were two of the outer peels.

Copper. All samples showed detectable copper. In the case of five of the sampling locations where the copper content of the soil was less than 0.001 per cent. the plant ashes showed a copper concentration higher than that in the soil.

Lead could not be detected in any of the soils, although it is possible that it may have been present at concentrations below the limit of sensitivity of the method. With two exceptions, lead could be detected in at least one of the fruit tissues from each sampling location.

Manganese. Fairly general distribution of manganese is indicated, this element being detected in all of the plant materials and in all but two of the soils. No consistent relationship is evident between the content of manganese in the soil and that in the plant materials. The pH value of the soil is often of more importance for the uptake of manganese by plants, however, than the total content of manganese in the soil owing to the precipitation of manganese in unavailable form at higher pH levels.

Strontium. In common with barium, its close relative, strontium exhibited considerable variability in the concentration in which it occurred in both soils and plants. All soils revealed detectable strontium with the exception of two from the Norfolk series. All of the plant tissues contained strontium. The tendency to be de-concentrated in the pulp, clearly exhibited by barium, occurs with less uniformity with strontium.

Titanium. Although all of the soils contained titanium, most of them in a concentration of at least 0.1 per cent. only three of the plant tissues revealed this element in a detectable concentration. In these cases less than 0.001 per cent of titanium was present.

Zinc. The occurrence of zinc was noted in all of the materials. A definite tendency for the element to be higher in the plant ashes than in the soil is clearly shown. The soils tend to contain about 0.001 per cent of zinc, as compared with about 0.01 per cent in the peel and pulp. An even higher concentration was found in most of the seed samples.

Molybdenum. The distribution of molybdenum is interesting in that the element was detected exclusively in the seeds, occurring in samples from five of the nine locations. The possibility of the molybdenum being derived from the soils is not contradicted by the failure to detect it in these materials, since it could have been present in concentrations below the spectrographic threshold for this element, in which case concentration by the plant might lead to its occurrence in plant tissues in detectable amounts.

Nickel. Nickel could be identified in only two of the soils. Although not found in any of the peel samples, it was detected in two of the pulps and in five of the seed samples. In this respect it resembles molybdenum somewhat, with its apparent tendency to be concentrated in the seed. The lack of pH data on all of the soils prevents drawing a general conclusion, but it is worthy of note that the fruit showing no nickel in any tissue grew on soils which could be expected to have relatively high pH values. This correlation, if borne out, would accord with the known

chemical behavior of nickel salts in precipitating out in insoluble form at higher pH levels.

Silver. Silver could not be detected in any of the soils. It was detected in a concentration of less than 0.001 per cent in the inner and outer peel and in the pulp from fruit grown on the marl soil. It was also found in the same concentration range in the pulp associated with Parkwood soil No. 1322. None of the seeds revealed silver in detectable concentration.

Zirconium. Zirconium could not be detected in any of the plant samples but was found in all soils except the marl.

GENERAL DISCUSSION

All of the samples were analyzed by direct spectrographing of the ashed materials. Thus the analytical data refer to the total content of each element in the samples analyzed. In particular, the values given for the soils do not necessarily correspond to the amounts of the elements which might be available for the use of plants. It is now well established that the ability of the soil to supply certain of the trace elements to plant roots depends as much on physicochemical conditions in the soil, such as pH, as on the total content of these elements in the soil. This fact must be considered in interpreting the soil data.

Since the sampling locations were in commercial groves, relationships between soil and plant composition may have been modified by spray applications in some cases.

The small number of sampling locations and the limitations of the method of analysis employed do not necessarily establish accurate and generally applicable predictions of the quantitative composition of Valencia orange tissues grown under Florida conditions. The mean values recorded in the lowest horizontal row of Table II are not given, therefore, with the intention of attempting to establish "normal" values, but only as a partial summarization of the data on these particular samples. Where no mean value is given the data were so variable that an average would have been meaningless. In some cases the mean was obtained after omitting one or more exceptional values. Where this was done the mean value is followed by an asterisk. The system of reporting data in range form is retained in the presentation of the mean values. The range limits corresponding to any given mean have no connection with possible minimum and maximum values that might be encountered with individual samples, but are intended merely to show the probable location of the mean value.

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ANIMAL RELATIONSHIPS

R. B. Becker and J. R. Henderson*

Livestock in the Bluegrass region of Kentucky, the Shenandoah Valley of Virginia, and parts of England, are world famous for their excellence from many standpoints. Animals thrive in those regions because the forages grown on these soils are known to contain optimum amounts of the nutrients essential to the welfare of animal life. In other regions, livestock thrive just to the degree that the soil has limited the level of some essential element in the forages utilized as feed (10).

Under range conditions in Florida, the amount and kind of available plant nutrients contained in the soil, as well as soil moisture conditions, largely determine both the quantity and quality of forage plants growing thereon. This, in turn, affects the welfare of cattle grazing on them. Investigations conducted on various ranges over the state have shown a striking relationship between soil conditions and animal welfare.

In the spring of 1930 before mineral supplements were used generally in Florida, Paul D. Camp (8) studied 7,100 head of cattle on 110,000 acres of land, these including all of the native cattle in one county in herds of over 50 head. The records were sorted into four groups in relation to the types of native pasture over which the cattle grazed. The pasture types were designated as flatwoods (mainly palmetto flatwood), deep sandy or blackjack lands, wet dark colored prairie lands, and hardwood hammock lands. The soils represented in these several types of pastures were:

Flatwoods—Leon, Portsmouth, and Plummer fine sands.
Blackjack—Deep phase of Norfolk fine sand.
Prairie—Bayboro fine sandy loam and Bayboro loamy fine sand.
Hammock—Fellowship, Arredonda, and Gainesville fine sandy loams and Fellowship clay loam.

By actual counts of cattle at the dip vats, and by interviews with individual owners, Camp obtained records concerning the numbers of calves produced, raised and marketed per hundred breeding cows, and the market returns per animal sold. These records were analyzed to determine the gross returns per breeding cow on each class of range as follows:

Range	*Average Calf Crop (Per Cent)*	*Animals Marketed (Per Cent)*	*Average Value at 2½ Years Old*[1]	*Gross Annual Return Per Breeding Cow*
Flatwoods	34.4	34.20	$30.20	$10.33
Blackjack	37.1	55.61	23.75	8.46
Prairie	54.1	53.80	35.50	19.10
Hammock	70.6	71.60	36.50	26.13

[1] Mostly sold as butchered beef.

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Information supplied to the senior author during 1929 and 1930 (3) by cattlemen over a wider area was substantiated by Camp's observations. The native vegetation growing on certain soils limited the number of calves produced, the number that survived, the ability of the dams to provide milk, and the resulting weight and grade of the calves at market age. At the same time, dairymen located on some types of land were quite successful in raising calves, while on other areas, the losses of calves were so great that some dairymen there had ceased trying to raise their own replacements. The fencing of pastures, and restricting the soil type over which cattle grazed aggravated the condition.

An investigation of the cattle on the various classes of pasture lands led to integration into a number of problems, some occurring separately, and others overlapping one another.

Several of these causes are as follows:

1. Inadequate intake of calcium.
2. Inadequate intake of phosphorus.
3. Inadequate intake of iron, or of iron and copper.
4. Inadequate intake of cobalt, iron and copper or a combination of this with low cobalt.

Inadequate calcium intake (1, 4) was seen among Jersey cows that were fed silage and hay grown on quite acid Blanton fine sand, Norfolk fine sand and Arredonda fine sand. The correction of this condition by the use of feeding bonemeal, and more recently by a combination of bonemeal and marble dust (calcium carbonate) was accompanied by greater strength of bones and a marked response in milk yields.

Inadequate phosphorus intake (5, 7) was seen among farm cows and range cattle subsisting entirely on native plants growing on Norfolk, Ruston, and Orangeburg fine sandy loam in one area and on Leon and Plummer fine sands in another. Fractured bones and depraved appetites were encountered among cows under such conditions. Cattle receiving phosphorus supplement in the form of bonemeal ceased chewing bone, leather, wood, etc., and tended to fatten under conditions which hitherto had caused them to remain spare or thin.

Inadequate quantities of iron, copper, cobalt or combinations of these in the forage have been observed to restrict growth and welfare of livestock on several types of soils (3, 6).

Anemic cattle on one pasture occupying a river terrace on which the dominant soil is Kalmia fine sand, recovered when supplied only a commercial grade of ferric ammonium citrate. On other pastures of Leon fine sand and the flat phase of St. Lucie fine sand, particularly, responses of dairy heifers, family cows, and range cattle were delayed until copper sulfate was added to the ferric ammonium citrate in a ratio of one part of copper to 50 parts of iron.

A supplement called "salt sick" mineral was used commercially over the state in two mineral mixtures. The second formula, with a reduced amount of salt, was used with cattle close to salt marsh or brackish water areas.

	No. 1	*No. 2*
Common salt	100	50
Bonemeal	None	50
Red Oxide or Iron	25	25
Pulverized $CuSO_4$	1	1

At the Experiment Station, controlled feeding trials were conducted using separate pure minerals to supplement Natal grass hay and corn grown on a light Norfolk fine sand. Jersey calves in these trials ceased growth when 5 to 8 months old. Only one calf thrived with the iron-copper supplement until, following clues from Australia (9, 11) and New Zealand (2), traces of a cobalt salt were added to the ration by Neal (12).

Reports of failures of livestock to respond to the use of "Salt Sick" Mineral No. 1 were received from stockmen having cattle on deep Norfolk fine sand in certain areas, Lakewood fine sand, Leon fine sand, Blanton fine sand, and on one area of muck. Addition of an ounce of cobalt sulfate to the iron-copper supplement used on these areas was accompanied by prompt responses by cattle, goats, and swine under observation in these cooperative field investigations.

Thus it is seen that cattle dependent on the forage grown on any definite area, are limited in their development and activity according to the amounts of certain minerals contained in that forage. A full understanding of the limitations of the soils within the available pasture areas in supplying these minerals, places the stockman in a position to use the correct supplements in his stock feed or mineral mixture, or to manage his soils in such a way that these minerals may be obtained from the forage produced thereon.

The series of photographs dealing with trace element as well as phosphorus deficiencies that follow, will be found very helpful in visualizing the true significance of soil and plant relationships to animal nutrition as faced by the animal husbandman, whether on the range or under more domesticated conditions in the barn lot or cultivated pasture.

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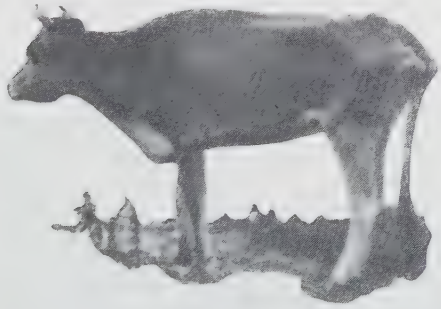

Figure 1.—Nutritional anemia ("salt sick") is characterized by lack of appetite, low hemoglobin in the blood, and muscle atrophy in the advanced stage.

Figure 2.—This cow was crippled permanently while on phosphorus-deficient range. Note the enlargement of the shoulder.

Figure 3.—The shoulder joint shows the erosion and roughened condition of the bones, as well as a break into the marrow cavity. This caused the crippled condition of the cow in Figure 2.

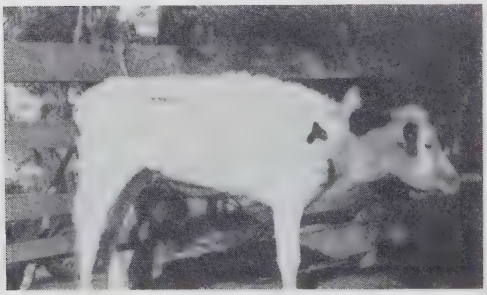

Figure 4.—A typical case of cobalt deficiency in a yearling Holstein heifer grazing on a Norfolk fine sand.

Figure 5.—The Holstein heifer shown in Figure 4 recovered fully when given access to a mineral supplement containing iron oxide, copper sulfate, and cobalt sulfate.

HUMAN RELATIONSHIPS

Ouida Davis Abbott and Chester F. Ahmann*

During the past twelve years a study has been made of human dietary deficiencies occurring among the people of Florida. While isolated groups of college students, rural women, and city children have been examined, the chief objective of this investigation was to determine the prevalence of nutritional deficiency diseases in rural children. Special attention has been given to nutritional anemia in relation to home-grown foods. At the present 10,000 subjects have been examined. More than three-fourths of them were rural school children, living in eight counties. Four of these counties were in the north and central parts of the State, three bordered the Gulf and one the Atlantic. Wide variations occur in the kind or proportion of different soils in the different counties and in different districts of the same county. A few of the people of the coastal counties were engaged in fishing and the production of citrus and truck crops, but general farming was the chief industry on the soils of the group as a whole.

In the first years of the investigation practically all of the children in the eight grades were examined; later, the examination was limited to those in the first four grades. Dietary studies were made of 3,000 of the children.

The diets as a whole were very poor. None of the children had food that provided a wide margin of safety. About 25 per cent had diets that could be rated as fair—not good, but passable. These were above the danger line but possibly were not far enough. The remainder of the group, about 75 per cent, had diets deficient in one or more nutrients and were below the physiological danger line, according to conservative standards of nutrition. Among the entire group, milk was used in only 28 per cent of the menus, butter and eggs in 30 per cent, leafy vegetables in 27 per cent, and fruit in only 20 per cent. The cereals were represented almost entirely by grits, corn meal, and white flour. The food items occurring most often were rice, grits, corn meal, sirup, white bacon, and biscuits. The year-round garden was rarely found and, outside the citrus section, fruit was scarce and limited to summer when wild berries and a few peaches and figs were available. The data collected indicated that these deficient diets were affecting the health of the people.

Carious teeth were found in about 45 per cent of the subjects. In many cases the incisors were carious and the 6-year molars were decayed before the 12-year molars erupted. A more or less cursory examination was made of the teeth of mothers and expectant mothers. The entire absence of teeth, the absence of front teeth, the absence of molars, the presence of many carious teeth, and malocclusions all gave evidence of poor tooth structure, due for the most part to inadequate diets—perhaps

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inadequate calcium and phosphorus. It was found that 33 per cent of the children using milk had teeth that were not defective, while little more than 10 per cent of those not using milk had good teeth.

Any defect that apparently bore some relation to diet was abnormal height-age relations. It was found that the 8-year-old girl was 2½ inches shorter than the standard given by Rose and 5 inches shorter than the standard given by Holt; the 13-year-old girl was 3 inches shorter than the standard of either authority. Similar observations were made of the boys. The 16-year-old boy was 3 inches under height by the standard of Rose and 4 inches by the standard of Holt.

Of all the defects found in these subjects, anemia was the most prevalent. Wide variations in the percentage of anemia were found in the children of the different counties and in different sections of the same county. All these children were attending school and were considered able to participate in the daily program. It is shown (Table 1) that 53 per cent of them were anemic—that is, hemoglobin values were below 11.3 grams; 23 per cent had border-line anemia, hemoglobin below 13.6 grams; approximately 10 per cent had values between 3.0 and 8.2 grams; and only 23 per cent had normal values. There was considerable variation in the percentage of anemia in the children of the different counties. County 3 had 28 per cent anemia; while the other seven counties had 63, 58, 46, 62, 60, 42, and 42 per cent in comparison. In county 1 there were four times as many children in the lowest hemoglobin group as in the highest; in county 2, five times as many; and in county 3, six times as many. The blood of these children in the low-hemoglobin group showed the characteristic reduction of hemoglobin and of cell size typical of microcytic hypochromic anemia. The average erythrocyte count in the anemic children was around 3,500,000 although total counts of 2,700,000 were seen. The hemoglobin concentration in the most severely affected children examined was as low as 2.89 grams. The color index was below 1—usually about 0.5—and the volume index varied from 0.5 to 0.7.

TABLE 1.—Grouping of 4,335 Children According to Hemoglobin Values.

County	Number of Children	Hemoglobin Values						Anemia Percentage
		14.6 16.0 gm. 91-100 %	13.6 14.4 gm. 85-90 %	11.4 13.5 gm. 71-84 %	9.8 11.3 gm. 61-70 %	8.3 9.7 gm. 51-60 %	3.6 8.2 gm. 21-50 %	
1	766	22	100	160	230	157	97	63
2	900	21	124	224	269	151	111	58
3	361	50	80	129	68	26	8	28
4	530	135	38	112	122	92	31	46
5	528	24	63	112	130	120	79	62
6	420	40	40	88	110	82	60	60
7	520	52	120	125	100	97	26	42
8	310	40	68	70	20	70	42	42
	4,335	23 per cent		23 per cent		53 per cent		

The data given in Table 2 show the percentage of anemic children as regards the incidence of hookworm and in relation to soil deficiencies as indicated by nutritional deficiencies of cattle. Hookworm infection is a factor which in the past has been held to account for the high incidence of anemia in the South. From the data presented, this infection could not account for the observed variations. Hookworm was widespread and should have contributed more or less uniformly to the occurrence of anemia; yet in certain schools where a large number of children were infected there was no more anemia than in schools where a lower percentage of infections occurred. It was found also that many children with hemoglobin values between 21 and 50 per cent were negative to hookworm.

It was observed often that the removal of the worm burden did not cause an improvement in hemoglobin, but on the other hand if iron were given to hookworm infected children the hemoglobin was restored to normal values without the removal of the parasites. Investigations on the degree of hookworm infection showed that many of the children were infected with a moderate number of parasites. It was found that a well-nourished child thus parasitized had little change in hemoglobin; however, when a poorly nourished one had the same number of worms the hemoglobin reached dangerously low levels. Apparently most of the general symptoms considered indicative of hookworm infection were due to anemia, for when iron was given, the pallor, the marked weakness, the excessive fatigue, loss of appetite, and edema gradually disappeared.

TABLE 2.—Variation in the Incidence of Anemia and Hookworm Infection of Children by Districts in Relation to Salt-Sick of Cattle.

County Number	Number of Schools	Number of Children	Anemia Percentage	Hookworm Percentage	Soil in Relation to Salt-Sick
1	6	408	76-89	55-75	deficient
	3	93	45-67	60-95	marginal
	1	265	32	65	normal to marginal
		766			
2	4	284	55-96	40-60	deficient
	2	254	33-47	35-50	marginal
	4	82	7-10	60-70	normal
		620			
3	4	95	52-60	30-50	deficient
	3	106	37-42	39-47	marginal
	10	159	0-23	0-80	normal
		360			
4	3	267	45-60	40-60	deficient to marginal
	4	264	20-39	59-70	normal to marginal
		531			
Totals	44	2,277			

The fact that the welfare of livestock of any particular region is limited by the fertility of pasture soils has been recognized for many years. At the Florida Experiment Station it has been demonstrated that the age-old condition of cattle, known locally as "salt-sick", is a nutritional deficiency occurring when the food is restricted to native forages grown on certain unfertilized sands and residual peats. Inadequate quantities of iron, copper, cobalt, or combinations of these and perhaps other elements were found to be the underlying cause of the disease. Supplemental salt mixtures containing these elements raised the hemoglobin and increased growth and reproduction. There was a possibility that people living on these deficient soils and producing much of their food thereon would suffer from the same deficiencies. In former investigations it was noted that the incidence of anemia was usually highest in the schools where the predominant soils of the district were classed as deficient in regard to salt-sick of cattle. The details of all of this have been treated quite exhaustively from the animal standpoint in the immediately previous paper of this symposium. The parallels existing between these nutritional deficiencies in animals and humans living on these various areas are indeed of very great interest.

The data show (Table 2) that in those districts where the predominant soils were classed as deficient in regard to salt-sick of cattle from 52 to 96 per cent of the children were anemic, but in the districts where the predominant soils were classed as normal or protective in regard to prevention of salt-sick, from 0 to 23 per cent were anemic.

It was found that the people of these counties could be divided into rather distinct groups according to food sources and food habits. These groups include families who, regardless of whether they live on normal or on deficient soil, obtain 70 per cent of their food from the soil; and families who live on the less-productive—and usually deficient—soils, and obtain varying amounts of food therefrom.

On the more productive soils practically all the meat, eggs, milk, fruit, vegetables, and chickens were produced on the farm or obtained locally. Only such staples as sugar, coffee, flour, bread, rice, grits, and condiments were bought regularly.

As the soils became less productive, less food was raised and a greater percentage was bought. In some sections the soils were so unproductive that farming as a means of livelihood had been discontinued and the family head either worked by the day—usually on a Government relief project—or was on direct relief. The families living on such farms usually had a part-time garden and a few chickens and hogs; but because of low incomes, ignorance of food values, habit, etc., the diet was composed largely of the cheap foods—rice, grits, biscuit, sirup, and white bacon. By modern standards, the diet of this group was below the nutritional danger line in several particulars. With these families, as with those who raised a larger percentage of their food, the foods highest in iron were produced on the farm or nearby.

Thus we have three groups: (1) Those families producing 70 per cent of their food, which was fairly adequate both as to quantity and iron; (2) those producing enough food, but food that was low in iron and

perhaps in other essential elements: and (3) those producing food inadequate both in quantity and quality and who, because of economic conditions, ignorance, and habit were subsisting on diets below the nutritional danger line.

In studying the iron content of vegetables grown in the home gardens of the different districts, turnip greens were selected as an index food. Turnip greens are found in practically every garden and are perhaps the most important source of iron. All the samples collected for analysis had been fertilized with commercial fertilizer and were healthy, leafy plants typical of the variety. Analysis showed that the iron in these greens varied from 258 p.p.m. when grown on the normal or protective soils to 56 p.p.m. when grown on the deficient ones. It is realized that in a diet made up of many iron-carrying foods, the differences in the iron content of turnip greens would be of minor importance. But to rural people depending almost entirely on home-grown vegetables for iron and using turnip greens the year round, the variation in the iron in these greens is one of considerable importance.

Through cooperation with the horticulturists of the several sub-stations in the State, turnip greens from a uniform seed source were grown at four diverse points in Florida. The fertilizer practices of each section were used, but all plantings and cultural practices were the same. The greens produced were dissimilar in growth habit, leaf form, succulence, and mineral content. The average iron from the above-mentioned locations varied from 84 p.p.m. to 238 p.p.m.[1]

Mustard greens likewise varied in iron in the different sections of the State from 60 p.p.m., when grown in certain sections, to 234 p.p.m., when grown on the heavy soils of west Florida. It must be borne in mind that none of the soils whereon these greens were grown was considered deficient, yet there was a considerable variation in iron.

A study was then made of the foods actually eaten by the farm families. In county 3 there are 240 farm families. It was considered that food samples collected from 80 of these families would be representative of the group. These samples consisted of an accurate duplication of all foods used in six consecutive meals by a child selected from each of the 80 families. In collecting the samples, the collector served an extra plate at each of the six meals with an amount of food equal to that eaten by the child. To this sample were added foods eaten between meals. These samples were collected from each family during the spring, summer, and winter. The foods were separated into those classed as predominately protein, carbohydrate, or fat. Each food group was weighed separately.

It was found that in the amounts eaten, the iron content of the food samples from children having diets below the physiological danger line varied from 2.2 to 6.0 mg. daily; food samples from children in families producing their food on soils classed as marginal or deficient in regard to salt-sick varied from 6.0 to 8.0 mgs.; those from children whose food was produced on the better soils and was fairly adequate both as to quantity and quality varied from 8.0 to 12.0 mgs.

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[1] Chemical Analysis of Plant Materials by H. W. Winsor, Assistant Chemist, Soils Department, Florida Agricultural Experiment Station, Gainesville.

That the anemic condition of the children was due to mineral deficiency was demonstrated by treating 400 anemic children with 100 mgs. iron as ferric ammonium citrate three times a day. Within 4 to 6 weeks after beginning treatment, all the subjects showed improvement and all except the ones with very low hemoglobin had values within the normal range.

Because of the improvement in hemoglobin with the administration of iron salts, it is not to be assumed that iron was the only element involved. The ferric ammonium citrate was in the form of U. S. P. green scales and had copper, manganese, and cobalt as impurities. However, with the regeneration and restoration of hemoglobin there was a tremendous improvement in color, activity, and appetite.

It should be made clear that deficient soils and mineral deficiency diseases are not localized in small areas in Florida, neither are they confined to Florida. Mineral deficiency diseases of cattle, as a result of soil deficiencies, have been identified in Nova Scotia, Massachusetts, North and South Carolina, Georgia, Florida, New Zealand, and Australia.

In addition to the mineral deficiencies already noted, areas deficient in manganese, calcium, phosphorus, copper, and zinc have been identified. The effects of a lack of these elements on plants growing in those areas is well recognized, but the effects of a lack of some of these elements on animal or human nutrition are not understood fully; neither is it understood what effect slight deficiencies of these elements will have when extended over a long period.

From this work it seems evident that while hookworm infection undoubtedly affects the degree of anemia, the high incidence in rural children is due primarily to diets low in iron. These low iron diets are occasioned not only by low incomes, ignorance of food values, habit, inertia, but also as shown in this study, by variation in home-grown foods. It appears then that soil deficiency operating through the plants grown thereon and ultimately on the health of the people is a factor that should be considered in any section where nutritional anemia is endemic.

Accordingly, it is obvious that one of our greatest needs in getting at a more complete understanding of this problem we are facing is a better knowledge of the type and distribution of our soils and their physical and chemical attributes as shown by a modern survey. Further than this, we need careful, long-time studies on the effect of a wide variety of soil treatments on the full chemical composition of plants growing on them as a basis for the further studies that are needed in human as well as animal nutrition. Above all, we should not permit ourselves to believe that the deficiencies we have now come to recognize are the whole story even for the present, let alone the future. It will be a wonderful day in which to live when our research programs can be so organized and supported as to anticipate some of these troubles in advance of their actual occurrence by the sheer strength and completeness of the work, rather than wait as we now so often do until they are thrust upon us largely by their unavoidable awfulness.

Figure 1.—Rural dwelling typical of many to be found in some of the counties studied. The four children, all of the same family, were born in the sort of soil environment which is evident in the natural surroundings of this home. All four of the children are anaemic, both boys also having very poor hearts. (Published with the permission of the head of the family.)

SYMPOSIUM: SOIL ORGANIC MATTER

Thursday P. M., May 30, 1940

INTRODUCTION

R. V. Allison,* Chairman

This morning we listened to a very interesting series of papers on trace elements which were so constituted and arranged as to cover the field in quite a broad and comprehensive manner. This was done particularly with the view of examining some of our soils and plants for these elements and showing how they are related to human as well as animal nutrition. Peculiarly enough, many times as much work has been done in this field on animal nutrition ("salt sick", etc.) as on human nutrition. I am sure, however, that you were convinced from the discussion of the latter that we have with us in this State and elsewhere on the Coastal Plains a human problem with which something must be done.

In our symposium this afternoon we want to develop the organic matter question in somewhat the same fashion. Thus we begin with a statement of the problem as viewed by one of the leading growers of citrus and many other things, including dairy cows, to be found along the Lower East Coast of the State. This is to be followed by discussions, successively, of where we are to obtain this organic matter, how it decomposes in the soil, and what it does in the soil after it has fully decomposed. All of this will be followed by a rather complete treatment of the physical and chemical characteristics of different types of peat especially as related to their use in the development of soils and the culture of plants.

The organic matter content of our Florida soils is exceedingly important from a number of standpoints; the most important of which is, doubtless, its capacity to take up and retain certain soluble plant food constituents. In this respect it is much more effective than the inorganic colloids of the soil more commonly called clay. Both types of colloidal materials function in such a way, however, as to remind one of the shelves of a pantry. In other words, these minute particles constitute that part of the soil upon or within which certain essential plant food constituents, including some of the trace elements, are lodged until needed by the plant. Unfortunately many of our most important Florida soils are much too deficient in both of these important components. It is significant, too, that it is only the organic type of material which it is within our power to do very much about, at least on a practical farm or grove scale. Too frequently, however, I fear we are inclined to feel that it is too difficult to do much of anything about it.

Without further introduction of the subject we shall now listen to the first speaker. Mr. Sexton, I am sure I speak the appreciation of the whole Society when I tell you that we are really glad you could find it possible to be with us and give us your views, as a grower, on this important subject.

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THE ORGANIC PROBLEM AS VIEWED BY A GROWER

WALDO E. SEXTON*

After receiving an assignment from Dr. Allison to prepare a paper on this subject I thought it would be very helpful to have a local discussion of the problem and invited in Dale Talbert who has charge of our grove operations and has had much experience in the field in growing citrus fruit: Harry Jones, who has a care-taker service in our area and has many years of experience with growing citrus on different types of soil; and Robert Edsall, who is connected with the American Fruit Growers and has an opportunity to study grove and soil conditions not only in this area but in many other areas in the State of Florida, to contribute to this symposium.

Our first approach to this subject was to define organic matter. We find that it is carbon compounds that are produced in plant and animal matter. Our remarks and questions will come from experiments and observations that we have made in the field.

We think that these organic matters or carbon compounds have remarkable properties for forming complex compounds, that they are able to reduce metals from their oxides and that these metals are changed by these organic materials. We know that these organic materials have ability to absorb and hold moisture. We know that carbon dioxide is thrown off in the decomposition of this organic matter and that it is essential to plant growth, and we have observed that where we have heavy windbreaks that the trees have finer foliage and finer fruit and we are wondering if this concentrated condition of the atmosphere in these areas which is heavily charged with carbon dioxide where the wind cannot change the conditions too quickly has anything to do with the character of the growth and quality of the fruit. We have observed that out in the open under similar conditions we do not get as fine foliage and as fine quality of fruit.

We think that we could possibly have a wind-break for every five acres of grove which would help conserve our moisture, and at the same time conserve our organic material and the carbon dioxide that is given off.

We are conscious of the fact that this natural organic matter in our soils is constantly being reduced and our problem is to find the best ways and means to replace it and how to handle it. At the present time we make a practice of hauling in from adjacent lands sawdust, grass and weeds onto our highly alkaline soils. We are trying to grow in our groves and under our trees grasses and weeds that will help supply this organic material. Would we get better results if these materials were plowed into the soil or should we be satisfied with merely putting them on top the ground? Is there any data on using pine sawdust from the mills that are cutting pine exclusively? How much additional fertilizer should be added to feed the soil microorganisms that are breaking down these

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organic materials? We feel that there is a definite relationship between nitrogen and organic material in the soil but we do not know what that fine balance of inorganic material and organic material is for best growth.

With the present price levels for fruit and organic materials I feel that I cannot afford to purchase organic materials in a sack and pay freight on them and distribute them on the soil but feel that we should buy concentrated material and grow cover crops or collect the organic matter locally and haul it on our grove properties. Am I correct in this line of thinking or could I afford to buy blood, bone, tankage, castor pomace and other organic materials and use them as plant food and would the additional results obtained from this practice warrant the additional expenditure of cash?

Harry Jones has given me a list of questions that are giving him some concern as a grower which I am listing as follows:

1. What is a clear definition of the term "Organic Matter"? Does it refer to partially decayed vegetable matter or does it refer strictly to completely decomposed vegetation?

2. Does our practice of growing grass and weeds in our groves and mowing three or four times a year add any appreciable amount of organic matter to the soil or are we just cutting grass?

3. Would discing once or twice each year to mix this vegetable matter with the soil aid in increasing the organic matter in our soil?

4. In connection with our grass growing and mowing practices is our fertilization practice in which we use rather large percentages of mineral matter conducive to or inimical to the accumulation of organic matter?

5. Other things such as base exchange capacity of the soil and its pH being OK what is the minimum amount of organic matter in terms of "parts per million" that is necessary to have what might be rightly regarded as a fertile soil?

6. If soil bacteria are essential to plant life and if organic matter is essential to maintain the bacteria, to what depth should the minimum amount of organic matter mentioned in the above question be maintained?

7. Are there any practical yet reliable field methods for determining the amount of organic matter present in our soils that do not require an expert or a laboratory to use them?

8. At one of the meetings of the State Horticultural Society Mr. F. M. O'Byrne of Lake Wales stated he had hauled in as high as ten tons per acre of muck into one of his groves and mixed it with the native soil by plowing and that after eight years he was unable to see any beneficial results. Dr. F. B. Smith of the College of Agriculture, University of Florida, once said, "The real significance of organic matter in the soils lies in its value as a food for the micro-organism of the soil. A soil may contain enough potassium for one thosand crops, sufficient phosphorus to last 500 years and an adequate supply of nitrogen for all plant needs and still be unproductive unless it contains a thriving population of soil micro-organisms." Is Dr. Smith's comment the answer to Mr. O'Byrne's lack of results?

9. Is there any scientific basis for believing that if we would abandon our present fertilizer practices and once a year put down an adequate supply

of properly bacterialized organic plant food, and hoe it in to mix it with the soil and protect the bacteria from the sun, we would promote greater tree growth, that our trees would be free of mineral deficiencies, that the bacteria would liberate these minerals from the soil so we could abandon our nutritional sprays and that we would produce better fruit and more of it at less cost, or is this just a fruit grower's dream?

Robert Edsall has also listed some of the problems that are confronting him at the present moment on which he would like to have help:

1. On good organic soils with high base exchange capacity what is the comparative value of natural organic fertilizers such as bone, castor pomace, blood, tankage, etc., as compared to inorganic fertilizer?

2. Is it better to mow a cover crop when it is green and succulent or when it is mature, hard and woody?

3. Do our Florida soils contain sufficient strains of bacteria to transform our applied plant food into forms available for plant assimilation?

4. How essential is it to incorporate a cover crop into the soil and if so, at what depths?

5. Do you lose any appreciable amount of plant food when the fertilizer is left on top of the soil, particularly in dry periods?

6. Does humus or organic matter have any effect on the availability of phosphate?

Dale Talbert, who is continually being confronted with the problem of producing quality fruit on soils heavily charged with organic matter, is wondering if there is any evidence that better results can be had by controlled water tables on these soils having the large supply of organic material sufficient to warant the additional high cost of maintaining a controlled water table.

In our area we have soils with elevations above sea level ranging from three to twenty feet with water tables that run from three feet below the surface to as much as two feet above the surface of the ground during our heavy rainy season in our drainage district.

We work with soils that vary from a pH as low as 3.5 up to 8.0 in a forty acre tract. We have soils that have no subsoil and have other soils that are underlaid with shell and marl.

We are 150 miles from the Experiment Station at Gainesville and 75 miles from Lake Alfred where experiments are being conducted on soils that are very different from our own. We have no laboratory equipment to check our field experiments. We do have the reputation of growing some very fine oranges and grapefruit of high quality on some of our soils and we feel that the answer to growing fruits of similar quality in other parts of the state is to be found by close study and analysis of the conditions under which these unusually fine fruits are produced if sufficient time and energy were spent on these soil and cultural conditions by scientists who have equipment to study, analyze and interpret the results obtained.

We would like to enlist the interest of the Soil Science Society of Florida and will cooperate one hundred per cent with the Experiment Station and any of their scientists to whom they may assign the task of helping us solve some of our organic matter problems in this particular area.

We feel that we are shooting in the dark and know very little about what is happening in our groves and soils compared to what we should know to make our operations as profitable as they could be and need to be if we are to compete with the present production and marketing problems that confront us at the present moment.

NATURAL SOURCES OF ORGANIC MATTER FOR FLORIDA SOILS

GEORGE E. RITCHEY*

The kind of crops grown to supply organic matter for soil improvement has for centuries been a matter of great concern to growers in many sections of the world. Other sections of the world, as in our own country, have not given the subject so much attention until recent times. The use of certain plants for cover crops and for green manure purposes is not of modern practice, but has been practiced by farmers of China, Japan, and some European countries as far back as history records agricultural practices.

The open sandy soils of Florida are especially in need of the incorporation of organic matter into their structure. Economy of operation demands that if the required amount of organic matter is to be added to the soil, it—or the greater part of it—must be raised on the fields where it is to be used. The transferring of all of this material from one place to another is too expensive to make the operation sound, except possibly when intensive methods of culture are in use.

The practice of growing cover crops for green manure to improve soil productivity for Florida's principal crops has led to the study of many of our legumes and grasses from the standpoint of their efficiency in soil improvement. The crops used for the purpose of incorporating into the soil for the improvement of soil fertility may be classified into summer and winter legumes, and summer and winter grasses. The legumes, because of their ability to fix nitrogen in the soil, are of course most to be desired as soil builders. All crops with the exception of a portion of those we speak of as native, grown for that purpose in Florida, have been introduced into the country at some time in the past.

The Florida beggarweed (*Meibomia purpurea*) is our most commonly grown legume. It is especially adapted to the sandy soils which are being used for the growing of summer crops as corn, cotton, and others which are cultivated in the spring months and left uncultivated during the summer. It is during the rainy season that the beggarweed makes its best growth. The amount of organic matter added to the soil by working in a crop of beggarweed is high. Stokes, Barnette, Jones, and Jefferies in Station Bulletin 253, report over 2400 pounds per acre as an average over seven years. One of these years was a failure, thus the actual annual yields during the other six years were considerably higher. Florida beggarweed, however, is subject to the uncertainty of an occasional failure.

Crotalaria, another summer legume, which fits well into the climatic requirements of Florida, comes to America as a native of Africa. *Crotalaria striata* and *Crotalaria spectabilis* are the two most widely grown

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species in citrus groves and in the general farming sections of the state. They are both well adapted to sandy soils in which organic matter is so much needed. The late maturing of the seed has made it impractical to grow either species on land which is to be planted to an early fall crop. This is being partially overcome by the use of an early strain of *Crotalaria spectabilis* which ripens seed the latter part of August or early September. This early strain produces less tonnage but will reseed and volunteer the following spring, thus with the exception of turning less organic matter into the soil, will give the same results as the larger, later strains. Stokes, et al, report *C. striata* as yielding nearly 5,000 pounds air-dried material per acre, which is about double the yield of the Florida beggarweed. Thus the total amount of nitrogen added by *C. striata* at the Citrus Experiment Station at Lake Alfred was more than double that added by beggarweed.

Cowpeas are another type of summer legume which can be grown in Florida for cover crop and green manure purposes. Most varieties of cowpea are susceptible to rootknot. The Iron, however, is practically resistant to attack and therefore can be grown successfully on soils infested with the rootknot nematode. The Brabham and the Suwannee show less resistance, but when the land is not highly infested will give good results.

Stokes, et al, record an average yield over seven years of about 2,000 pounds per acre of air-dried material turned under at the Citrus Experiment Station.

Velvet beans are often planted with corn or grown alone for the purpose of incorporating into the soil. The plant, however, is more often grazed in late fall or early winter and a comparatively small amount reaches the soil as green manure. Its long, winding vines make it difficult to incorporate into the soil without the use of heavy machinery. The total yields of plant material from this crop are similar to those of cowpeas on the ordinary sandy soils of the state.

The interest in Alyce clover (*Alysicarpus vaginalis*) has been running high the last two or three years. This legume has not been grown as a soil improvement crop on experimental plots at the Florida Experiment Station, but has been used as a cover crop in citrus and tung oil groves in different parts of the state. Its adaptation to soil types, climatic relationships, fertility requirements, and its effect on the soil have not been determined. However, it has been advertised rather widely. The plant is at least partially susceptible to rootknot, but indications are that it is quite tolerant of the ravages of this disease unless growing under poor conditions or on heavily infested soil.

The seeds of Alyce clover do not germinate until the soil has warmed up in late spring. The plants begin seeding in late August or September and most growers are yielding to the temptation of removing the crop for hay. The hay is reported as being comparable to alfalfa. It is quite possible that this legume will make a valuable crop on fields where early fall and winter planting is desired, but certainly will have little value as a source of organic matter if the tops are removed for forage.

Other summer legumes of more recent introduction are under observation at the Florida Station. One which may be mentioned as showing promise is *Indigofera hirsuta*. This plant has one or two serious limita-

tions, however, which must be overcome before it can be recommended for general use.

One of the greatest problems the investigators are facing is that of a winter growing legume which can be used as a green manure and which can be incorporated into the soil early enough for the spring planting. It is desired that a winter legume produce seed early enough to enable it to volunteer from year to year.

The vetches have been used to some degree in West Florida. The hairy vetch has received the most attention until recently there has been a swing of interest to the Augusta vetch (*Vicia angustifolia*). The hairy vetch has lost favor due to its inability to seed and volunteer. The Augusta vetch seeds heavily and when allowed to ripen seed in the spring will volunteer and produce a good crop the following winter without reseeding. The task of the isolation of an early strain is being attempted at the Florida Station. A strain has been developed which it is hoped will at least partially meet this requirement, and a seed supply is being developed for more extensive trials.

The Austrian winter pea (*Pisum arvense*) has been grown successfully in Florida. Its greatest enemy is the aphid, which often destroys the crop before satisfactory growth has been reached. The use of this plant, however, has been largely discontinued.

The narrow-leaf lupine, which was grown in Europe for soil improvement purposes more than 2,000 years before Christ, is a crop which was introduced into the state by the United States Department of Agriculture, and has been grown successfully at the North Florida Experiment Station. It is a winter legume which is easily grown and makes an enormous tonnage. Mr. J. D. Warner in Florida Experiment Station Press Bulletin 541 reports an average yield of over 25,000 pounds of green material per acre, produced on the station farm at Quincy by March 22, and over 35,000 pounds by April 14. He also reports a yield of over 1,100 pounds of seed per acre. The crop is susceptible to several serious diseases which seem to be more common in Central than in West Florida. Efforts are being made to isolate disease-resistant strains which will extend the limits of this plant farther south and into sections where it does not seem adapted at present. It is necessary to plant new seed each autumn due to the failure of the seed to remain dormant in the soil during the summer months. This is not a serious matter, however, when such high yields of seed can be obtained as is reported by the North Florida Experiment Station.

The use of grasses as green manures has not been practiced as extensively as has the use of legumes. Grasses, however, produce good yields of organic matter, both above and below the ground. Natal grass grows as natural vegetation in most parts of the state. It produces a good yield of organic matter which when incorporated into the soil produces results quite comparable to those obtained from the use of legumes. Stokes, et al, report a 6-year average yield of 3,400 pounds of air-dried grass per acre on plots in orange groves at Lake Alfred, the yields being higher than those of any of the legumes except *Crotalaria striata*. They state in the Florida Experiment Station Bulletin 253 that

"Despite a higher percentage of nitrogen in the tops of cowpeas, velvet beans, and baggarweed, as compared with natal grass, these leguminous plants returned only insignificant increases or actual decreases of nitrogen to the soil in comparison with the amounts returned by natal grass."

Other sources of organic matter for soils which should not be overlooked are the refuse of regular crops and various types of native vegetation which springs up without any effort on the part of the grower. Natural growth is one of the important sources of organic matter. Consequently, the individual who makes use of it has a really cheap source which should yield good returns.

While this paper has dealt with the tops of plants only, it must be remembered that all plants produce an abundance of roots which are also very valuable even though much less obvious sources of organic matter. Removing the tops, however, for hay or by burning to afford easier cultivation, robs the soil of an abundance of nature's storehouse supplies. Except in special cases, therefore, the practice should be avoided on soils which are to be used in the future for crops.

FACTORS AFFECTING THE DECOMPOSITION OF ORGANIC MATTER IN SOILS UNDER FLORIDA CONDITIONS

F. B. Smith*

Realizing the importance of organic matter in soils and the rapid rate of its disappearance from most of our Florida soils, some of us are wondering if it would not be fortunate if some way could be devised to prevent the rapid decomposition of this organic matter in our soils. Now it is not my purpose to discuss the wisdom of preserving the organic matter in soils, important as organic matter may be. I would rather have you consider the circumstances which condition the fate of organic matter in the soil and then draw your own conclusions regarding how this important constituent may be kept in the soil.

The factors which determine the length of time organic matter will remain in the soil, and, consequently direct our efforts in organic matter maintenance, may be grouped under three categories, namely, (1) those having to do with the organic matter itself, (2) those having to do with the agencies of destruction, the microorganisms, and (3) those factors governing the activities of the microorganisms.

Let us consider these factors in order and with this concept of organic matter clearly in mind; namely, that the organic matter consists primarily of material of plant origin, in the unaltered, undecomposed state; mixed with a mass of partially decomposed and decomposing material, the intermediate products of decomposition; and some of the final end products of decomposition, such as carbon dioxide, water, ammonia and the ash constituents. Thus, it is seen that we have the unchanged material on the one hand and the changing material together with the end products which are no longer organic matter, on the other. Under a given set of conditions, the length of time required to change this material from the unaltered state to the final end products varies with different kinds of material. It would require a given number of men a longer time to raze a four-story structure of steel and concrete than it would a flimsy, wooden structure of the same size. Some plant structures are more readily decomposed than others and plants containing a large proportion of the readily decomposable constituents naturally decompose more rapidly than those containing a large proportion of the less readily decomposable materials. Numerous investigations have shown that plants containing a large proportion of simple sugars, starches and cellulose decompose rapidly, provided sufficient nitrogen is available and other conditions are favorable. On the other hand, plants containing a large proportion of the hemicelluloses, lignins, waxes and resins decompose slowly, even under the most favorable conditions. The sugars, starches and cellulose decompose quite readily under favorable conditions to the end products, carbon dioxide and water. The period from the unaltered material to

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the end products is relatively short. On the other hand, plant materials containing considerable proteins, in addition to the sugars, starches and cellulose, as the legumes, persist in the soil in the intermediate or decomposing condition longer than materials of a wider carbon-nitrogen ratio. For example, in our experiment with various materials it was found that after 35 days 56% of velvet bean material added to the soil had decomposed and only 28.8% of crabgrass was decomposed during the same time but after 374 days 20.2% of the velvet bean material applied persisted in the soil and all of the crabgrass was decomposed. Numerous other investigations have shown that materials of a wide carbon-nitrogen ratio decompose somewhat more slowly, especially during initial stages than materials of a narrow carbon-nitrogen ratio but more partially decomposed material, or humified material if you like, is produced from plant materials of a narrow carbon-nitrogen ratio. This is of large practical value, especially in our open sandy soils of Florida where organic matter disappears rapidly. The stage of growth of the plant is also an important factor in the rate of its decomposition. Young plants usually contain a greater proportion of the sugars, starches and proteins than the mature plant. These are the constituents which decompose readily. The mature plant, on the other hand, is usually woody, contains a relatively high content of the hemicelluloses and lignin, materials which decompose more slowly than the sugars, starches and proteins.

The physical condition of plant materials may exert as profound influence upon its rate of decomposition as the chemical composition. Green, succulent plant materials decompose more rapidly than the dead, dry materials and the degree of subdivision has a marked effect. Finely ground materials with an enormously increased surface area exposed to attack by the microorganisms will decompose more rapidly than the unground material.

Practical application of all these facts is made in our efforts to obtain wherever possible legumes as cover crops and to plow them under while in a green succulent condition. Sometimes this is difficult but wherever possible it is the best practice. The kind of material used bears an important relation to the rate of decomposition and the quality of the intermediate products produced.

The kind of organisms present in the soil and the relative abundance of the different groups present are factors governing the decomposition of the organic matter in the soil. If there were no organisms in the soil, the scanty supply of free carbon, nitrogen, phosphorus and sulfur in nature would soon be tied up in plants and further plant production would be impossible. We can all agree that that would be bad, indeed. However, it would insure preservation of the organic matter. Fortunately, there are many organisms everywhere in the soil which bring about the decomposition of organic matter, especially where conditions are favorable, they do not have to be added, and all plant materials can be reduced by the microorganisms back to their ultimate constituents, notwithstanding the fact that some constituents, such as lignin, are not readily attacked by a large number of microorganisms.

The largest group of organisms decomposing organic matter are the one celled plants called bacteria. One-fourth teaspoonful of a rich garden soil may contain several billion of these bacteria. Another group of organisms related to the bacteria and possibly second only to the bacteria in relative abundance is one in which many cells are united into filaments which spread out and reach out in all directions. These organisms give the appearance of thread bacteria and are called the Actinomyces. A third group of organisms universally present in soils but usually much less abundant than the bacteria and Actinomyces is the filamentous fungi or molds. Then there are the fleshy fungi, macroscopic organisms of importance in the decomposition of organic matter, especially under forest conditions. The algae and the protozoa are other groups which may be of more importance in organic matter decomposition than is known at present.

Among the various groups of microorganisms, some are restricted in their activities, and are known generally as special purpose or physiological groups. For example, *Cytophaga hutchinsonii* secures its growth energy only through the decomposition of cellulose, that is, it is incapable of utilizing other carbonaceous materials as food. On the other hand, many organisms are capable of utilizing a wide variety of materials or plant constituents as sources of energy. The Actinomyces are able to decompose nearly all plant constituents quite completely. The varied capabilities of the different groups of soil microorganisms may account, in part at least, for the indefinite mixture of intermediate products in the mass of decomposing organic matter. Thus, a shift in relative numbers of the various groups of organisms present may result in an accelerated decomposition of certain constituents or a decreased rate of decomposition of others. Then, in addition to all these variables is the matter of biological interactions, an important factor which must not be overlooked. This effect may be favorable or it may be unfavorable.

The third group of factors limiting the decomposition of organic matter in soils and possibly the most important from the standpoint of soil management is the matter of environmental conditions affecting the microorganisms. The factors usually considered of much importance in this respect are moisture, temperature, aeration, reaction and nutrient elements.

Since the microorganisms swim to work it is obvious that they do not work if there is not adequate moisture. The optimum moisture content appears to be about fifty per cent of the saturation capacity of the soil for most beneficial microorganisms. As the moisture content of the soil increases beyond this amount aeration is decreased markedly and an entirely different flora and fauna becomes active than at lower moisture contents. There is some decomposition under anaerobic conditions but it is not as rapid nor as complete as under aerobic conditions. There may be also an accumulation of intermediate products some of which may become highly toxic under these conditions.

The temperature conditions in the soil exert a large influence on the rate and amount of decomposition which takes place. The minimum temperature at which the soil organisms are active is about 10°C., although

some bacteria may be active at 0°C. Most soil microorganisms are killed by temperatures of 50° to 60°C., but the thermophilic bacteria appear to be most active at 70° to 80°C. Soil temperatures of 30°C promote rapid microbiological action, and where the winter temperatures are mild decomposition is enormously rapid, especially if other conditions are favorable.

The reaction or hydrogen ion concentration of the soil has an important influence on the decomposition of organic matter in soils. The bacteria and Actinomyces are sensitive to acid conditions and are not so active in extremely acid soils. The molds, on the other hand, are tolerant of acid conditions and consequently, in acid soils the decomposition is mainly by this group of microorganisms. Most microorganisms tend to adjust the reaction of the medium to a point most favorable for their growth. That is, if the pH is too low, it is raised and if too high it is lowered, by the organisms. Extremely acid soil conditions are usually associated with a lack of bases and in many cases, no doubt, the injurious effect of acid soils is a deficiency of available calcium and magnesium rather than a harmful effect of the hydrogen ions.

It should be remembered that most of the microorganisms of the soil are plants and, as such, have need for all of the essential elements required by the higher plants. Nitrogen, phosphorus, potassium, calcium, magnesium and sulfur are possibly among those required in greatest amounts. Iron, copper, manganese, zinc, boron and possibly others are required in smaller amounts. Naturally a deficiency of any of these elements will be reflected in the decomposition of organic matter in proportion to the needs of the microorganisms.

THE PHYSICAL ACTION OF ORGANIC MATTER IN FIXING PLANT FOODS IN THE SOIL

G. M. Volk*

The two major factors determining the fertility or plant producing ability of any soil are its water relationships and its ability to supply fertility elements to the plant. For the purpose of this paper the first will be disregarded and attention concentrated on the role of the soil in furnishing the essential fertility elements.

It is common knowledge among agriculturists, that very sandy soils carrying little colloidal mineral matter or organic matter will produce only very poor crops under field practices even though water and fertilizers are supplied abundantly. Yet it has been adequately demonstrated that pure sands and even water cultures will support vigorous plant growth if the fertility elements are applied in the proper form and ratio *and are held against movement away from the plant roots.* This is accomplished by restricting removal by flow or drainage such as is done in water cultures. It can be assumed, therefore, that the soil mass itself is not essential for plant growth, but under field conditions needs to act only as a retainer of nutrients pending such time as the plant demands them. True, soil minerals and organic matter are in a continuous process of decomposition, thereby liberating nutrients, but these nutrients can be artificially supplied by fertilizer amendments, thus making the decomposition process not a vital function but merely a supplementary one. This process is, nevertheless, highly desirable because it makes available the most economical supply of plant nutrients. Unfortunately mineral decomposition is not sufficiently active on soils of low mineral reserve to meet the needs of vigorous growth.

Two types of retentive constituents, namely, mineral colloids and organic matter, exist in the average soil. The first is inorganic in nature. It is composed of finely divided mineral particles. Its retentive power for amendments is small compared to that of organic matter and it exists only in minute quantities in sandy soils. Its action is so similar to that of organic matter that only the latter will be discussed in detail.

Organic matter or "organic exchange" is very effective as a retainer of nutrients. Its existence and replenishment is entirely dependent upon cultural practices, plant growth, and soil amendments. It becomes the dominant prerequisite to fertility of sandy soils.

Any salt such as muriate of potash, calcium chloride or sulfate of potash is the product of a base neutralized by an acid. Muriate of potash can be made by neutralizing potash lye with muriatic acid. Soil organic matter acts like a weak acid and has a strong attraction for basic constituents such as the potash in muriate of potash. If the organic matter has absorbed all of the base that it can hold, it is said to be "saturated"

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with bases. If another fertilizer salt is added to such a soil, some of the bases of the new salt replace those held by the organic matter. The base displaced from the organic matter then unites with the acid portion of the applied salt and is leached out with the drainage water.

If the organic matter is "unsaturated", it contains soil acid (adsorbed hydrogen). This also may be replaced by bases of added amendments although not as completely as can previously adsorbed bases be replaced. A simple experiment can demonstrate the retentive power of organic matter for certain nutrient elements.

Two samples of soil, one a decomposed peat representing the extreme in organic matter content, and one a Norfolk fine sand representing a soil very low in organic matter content, are placed in separate small glass funnels. Each is first leached with a dilute acid to remove all calcium, followed by water to remove the free acid retained by the soil. To each soil is added a small amount of calcium chloride. (Muriate of potash, sulfate of ammonia or any similar fertilizer salt could be used.) The calcium salt is allowed to remain in the soil for a few minutes to allow reaction with the organic matter to take place.

The organic soil should theoretically take the calcium from the calcium chloride salt and let the chloride (muriatic acid portion of the salt) pass on. When the organic soil in the funnel is leached with distilled water, we find by test that the solution coming through the funnel is free from calcium. A further test shows that the chloride is present, proving that the soil is retaining the calcium (base) and allowing the acid portion of the salt (chloride) to pass on.

A similar test of the Norfolk fine sand shows that both calcium and chloride came through the soil in abundance. This soil contained relatively little organic matter, therefore had little ability to hold the basic constituent of the salt.

To further prove that the organic soil actually held the calcium, the soil was subsequently leached with another salt. The base from the new salt replaced the calcium and it passed through the funnel so that the solution collected showed a strong test for calcium.

Obviously the retention and replacement of bases in the soil is an intricately balanced setup. It is readily understood why over liming can supply too much calcium so that the potash will all be replaced and lost in the drainage water. A certain amount of liming is desirable (within limits of tolerance of the plants in question) because it raises the pH thus increasing the base holding capacity of the organic matter. Bases of salts such as muriate of potash will readily replace hydrogen in low pH (acid) range, but the total amount of bases held is so small that it becomes a definite limiting factor in soils of low total organic exchange such as our sandy Florida types.

In summarizing, soils low in natural mineral exchange must depend upon organic matter for retention of basic fertility soil amendments such as potassium, calcium, magnesium, zinc and ammonia, if these amendments are to be held from one time of application to the next so that plants will have a continuous, rather than spasmodic, supply of available nutrients.

PEAT AND ITS USES

Selman A. Waksman*

WHAT IS PEAT

In well aerated field and garden soils, the yearly production of plant residues is accompanied by their destruction, partly through the agency of man and animals, but largely through the activities of the numerous microbes inhabiting the soil. Under these conditions, organic matter will not accumulate at all or only in very limited amounts. However, when insufficient aeration or excess acidity prevent the rapid destruction of the plant residues, by limiting the activities of the microbes, the organic residues are only partly decomposed and tend to accumulate. This partly decomposed organic matter is known as *humus*. When the formation and accumulation of humus takes place under water or in a water saturated environment, a type of humus is formed which is designated as *peat*. The water basin in which peat accumulates is spoken of as a *bog* or as a *peat bog*.

The term peat is thus applied to an accumulation, in water or in a water saturated condition, of organic matter rich materials of plant origin, consisting of partly decomposed plant remains and of certain products of plant decomposition. Fresh peat is yellowish brown to brown in color and fibrous in structure; when exposed to the air, it darkens and may become distinctly black. Peat varies considerably in structure, in water holding capacity and in chemical composition, depending on the plants from which it was derived, upon the conditions of its formation and on the extent of its decomposition.

Various other designations have been applied to peat, namely, muck (reed and sedge peat, well decomposed), turf, moor, moss (usually sphagnum peat) and simply humus. A peat bog is frequently spoken of as a marsh, a swamp, a heath, a morass, a fen, etc. These names are either of local significance or are used to indicate certain types of peat.

Peat is usually acid in reaction, the acidity varying considerably with its nature and origin. Although fresh peat is usually of a fibrous structure, some lose it readily upon decomposition and drying, and become granulated. Peat has a very high water-holding capacity, being capable of holding 300 to 1500 per cent of water on the basis of its dry weight. It is largely organic in nature, the loss on ignition varying from 60 to 98 per cent, on a dry basis. It is high in nitrogen, usually from 1 to 3 per cent; however, it is very low in nutrient mineral elements especially in potassium and phosphorus and frequently in the trace elements, especially copper, and to some extent manganese and others. When obtained fresh, the moisture content of peat varies from 80 to 95 per cent; in a marketable state, the moisture is usually between 30 to 70 per cent, depending upon the nature of the peat.

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When added to soils or placed in composts, peat is found to be more resistant to further decomposition than are fresh plant and animal residues, thus making it a valuable source of organic matter for soil improvement.

HOW PEAT IS FORMED

The fundamental factors which influence the formation of peat and determine its nature are largely functions of climate, and of soil and water relations. These control the nature of the vegetation as well as the processes of decomposition of the plant residues. Peat is usually produced on land which is poorly drained and where the water may collect and stand permanently. The peat-forming plants find these conditions favorable for their development, especially when the high humidity of the air prevents evaporation and when the temperature is low; the decomposition processes thus become very slow, and gradually lead to the formation and accumulation of peat.

In the development of a peat bog in basins filled with water, algae and other aquatic plants, pollen and leaves of higher plants, and also the organic and inorganic particles in the dusts and streams, first accumulate, thus forming the bottom layer of the peat deposits. This process is very slow. However, as soon as the basin fills up and the waters become shallow, a zone of aquatic vegetation appears gradually leading to the growth of sedges, reeds and other aquatic plants. This process continues until the level of the bog has been raised to that of the surrounding country. Growth of various grasses and shrubs, as well as of a variety of sphagnum mosses will now take place. Coniferous trees appear later and are followed by deciduous trees. At that stage, the surface of the peat has reached above the level of the bog, with the result that decomposition processes are able to keep pace with the accumulation of the organic matter. The water level may then become suddenly or gradually elevated, as by subsidence of the land; the growth of the trees will be stopped and lower plants which are adapted to an aqueous environment again appear. A new period of peat accumulation begins and the whole plant association may be changed when these new conditions are established. The nature of the vegetation depends largely upon the nature of the waters entering the bog, especially mineral content and reaction, as well as upon the nature of the bottom material and upon climatic conditions.

Under certain climatic conditions, notably in damp northern climates, similar to those prevailing in northern Europe and in the Northeastern and Northwestern parts of the United States and Canada, another type of vegetation appeared, following the forest or grass stages; that vegetation consists largely of various mosses, belonging to the sphagnums. These mosses grow above the level of the surrounding country and do not depend upon drainage waters for their sustenance. They depend chiefly upon rainfall and upon atmospheric humidity for their moisture and nutrients. They actually lift the water level above that of the surrounding country. A type of peat now accumulated to the extent of 10 to 30 meters above the lower layers, giving rise to a dome-shaped type of bog. Because of the relation of these two types of peat bogs to the surrounding country,

the first type of bog is designated as a lowmoor and the second as a highmoor type.

On making a vertical cut through a peat formation, one obtains a "profile", which shows a series of stratified layers which have originated from different plant residues, as shown in Fig. 1. The lowest layer is usually of sedimentary origin; it frequently contains a large number of shells of animal origin which lived on the bottom of the lake before the process of bog formation was far advanced. As the bog became filled, higher plants began to grow, giving rise to new types of peat, as shown in the profile. In a peat profile, one may find blackened, thoroughly decomposed layers. These indicate a period of low water level or drought. The occurrence of such layers at different levels indicates that such conditions have occurred at different times during the period of peat formation. The presence of a layer of poorly decomposed fibrous plant residues points to a previous period of prolonged precipitation and a rise in water level. A series of stratifications in the peat profile are thus produced, giving rise to a profile characteristic of each bog.

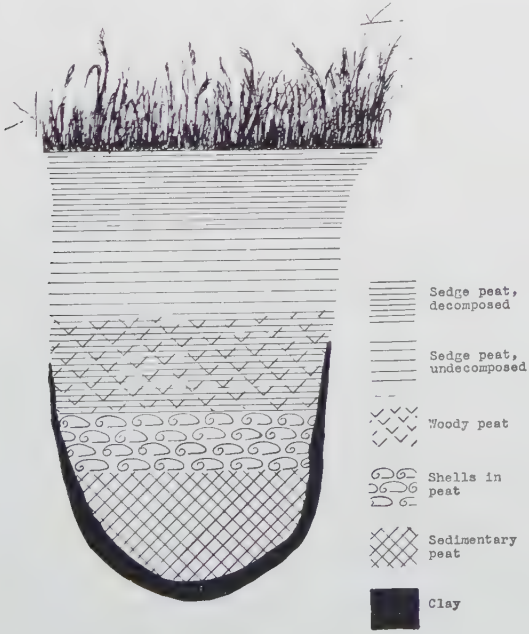

Figure 1.

TYPES OF PEAT

Because of differences in the nature of the vegetation from which peat is formed and because of differences in conditions of its formation and degree of decomposition, peat varies considerably in physical properties and in chemical composition. These differences led to a great confusion in designating peat and in determining the degree of its usefulness.

There are several causes for this confusion: 1. Different forms of peat differ considerably in appearance and in composition, due to variations in vegetation and in the conditions of peat formation. 2. Differences in the utilization of peats for practical purposes often led to a variety of names for designating the same general type of peat. 3. When drained, peat undergoes considerable decomposition and changes in appearance and in composition; this led to the use of different names for the same peat in different stages of decomposition. 4. In many cases, names used in one language were transferred to another, without due allowance for names already existing.

At the present time, however, four distinct types of peat may be recognized, namely,

1. *Peat moss* (also designated frequently as sphagnum peat, highmoor peat, moss, and even only as peat). This type of peat is fibrous in nature, yellowish to light brown and brown in color. It is acid in reaction (pH 3.0-4.5), is low in nitrogen (about 1 per cent, on a dry basis) and in ash (1.5-3.0 per cent, on a dry basis). It has a high water-absorbing capacity (about 600-1500 per cent, on a dry weight basis). This type of peat is placed on the market in various grades depending upon the degree of fineness of shredding. The coarser material is used for stable bedding and poultry litter and the finer particles for horticultural purposes and soil improvement. Its moisture content is about 30 to 35 per cent.

2. *Sedge and reed peat* (also designated as muck, lowmoor peat, and frequently as plain humus). This type of peat is usually dark brown to black in color, powdery when dry, and with comparatively little fibrous material. It is less acid in reaction (pH 4.5 to 6.5); it is high in nitrogen (2.0 to 3.5 per cent, on a dry basis) and in ash (5 to 30 per cent, on a dry basis). The organic matter content, or loss on ignition, of this peat, ordinarily varies between 70 and 95 per cent, on a dry basis. It has a much lower water absorbing capacity than peat moss (250 to 600 per cent, on a dry basis). The moisture content of this type of peat obtained on the market is usually 60 to 70 per cent. A distinction is sometimes made between *raw peat*, or freshly obtained material, and *cultivated* peat, when it has been allowed to aerate for a period of several months to a year, either by surface cultivation or in the form of composts. Frequently composts of this type of peat are made with other organic materials, stable manure or inorganic salts, notably nitrogen salts and phosphates.

3. *Forest peat* (forest litter, forest mold, oak leaf mold, tree mold, peat mold). This type of peat is brown to dark brown in color, fluffy and somewhat fibrous (less, however, than peat moss). It is acid in reaction, especially when derived from cedar and other conifers (pH 3.8-5.5), with an abundance of fine particles of macerated wood. This peat stands midway between the other two types in chemical composition, namely in nitrogen content (1.0-2.5 per cent) and in ash (3-20 per cent). It also stands midway in water-absorbing capacity (400-800 per cent, on a dry weight basis). Due to the presence of coarse, woody particles, this type of peat, unless very carefully separated or composted is not as valuable a material for soil improvement as the previous two types.

4. *Peat soil or peat humus* (sedimentary peat, peat compost). This type of material is similar to ordinary top soil high in organic matter. It may have originated from peat, by extensive decomposition or may have been produced by composting or mixing of peat with soil. The organic matter content of this material may vary from 20 to 60 per cent, on a dry basis. The nitrogen content varies considerably, usually between 0.2 and 1.5 per cent. Its value should be determined on the basis of organic matter content.

In addition to these four types, several others are commonly encountered. These are less abundant, less significant or less important; some of them represent mixed types and can be conveniently grouped with one of the above.

CHEMICAL AND MICROBIOLOGICAL NATURE OF PEAT

Although in appearance the plant residues in the peat may appear to be well preserved and to have undergone little change, a chemical and microbiological analysis will show that a number of transformations have taken place, in the process of formation of peat from plants. The peat bog is not sterile, as is frequently stated, although it is practically free from human and animal disease producing organisms. It contains an abundant population of microbes, mostly bacteria, capable of living in the water environment. When the plants die, the leaves, stems and roots are attacked at the surface of the bog by a variety of organisms, ranging from bacteria to insects. These organisms rapidly attack and destroy some of the plant constituents. However, the plant materials thus become only partly digested, the residual products being poorer in certain chemical constituents and richer in others. In the case of mineral elements, for example, peat is poorer in phosphate and in potash than the plants from which it has been formed; however, it is richer in silica; this is due to the fact that the first two minerals are rapidly liberated and are reconsumed by the growing plants, whereas the silica is left in the residue to accumulate. The same may be said of certain organic constituents: the carbohydrates (sugars, starches, cellulose) decompose readily, whereas certain complex phenol derivatives, designated as lignins, accumulate. The nitrogenous materials usually increase in the case of lowmoor and forest peats and decrease in highmoor peats, due to various conditions of decomposition. Once the particular layer of peat becomes submerged and superimposed by a fresh accumulation of plant residues, the decomposition processes are considerably delayed and are carried out further only slowly and largely by a few bacteria, anaerobic in nature.

Chemically, peat thus represents a transformation product of the plants from which it has been formed. Its composition depends upon the nature of the plants, bog conditions, as well as nature of microbes inhabiting the bog. In order to determine the usefulness of a particular bog and the utilization of the peat material, it is essential to have a knowledge of the physical and chemical properties of the peat.

Tables 1-4 give a clear idea of the differences in the chemical nature of several types of peat and their decomposition.

TABLE 1.—Chemical Composition of Certain Florida Peats (Hammar)

Constituents	Saw-grass Peat *per cent*	Sedimentary Peat *per cent*	Intermediate Peat *per cent*
Organic Matter	86.37	44.52	77.65
Nitrogen	2.79	1.47	2.65
Ash	13.63	55.48	20.35
SiO_2	4.12	35.81	9.87
Fe_2O_3	1.01	5.04	1.81
CaO	5.21	3.81	5.25
MgO	0.10	0.09	0.13
P_2O_5	0.42	0.48	0.42
Al_2O_3	0.30	5.08	0.78

USES OF PEAT

The major uses of peat and of peat lands throughout the world and especially in the United States are connected with agriculture. This includes its use for (a) the growth of field and garden crops; (b) for soil improvement; (c) as a litter in stables and poultry houses, and (d) for mulches and other horticultural purposes. Peat has also found use in a number of industries, chief among which is as a source of fuel. However, in the United States the extensive deposits of coal and oil prevented the use of material, like peat, which has a lower calorific value and a much higher ash content.

(a). *Use of peat as an agricultural soil.* The reclamation of peat lands and their utilization for farming purposes probably offers the greatest possibilities in this country. Black, thoroughly decomposed friable peat in a deposit that has been well drained, aerated, and successfully cultivated for several seasons is suitable for the growth of many crops. For the succesful cultivation of these crops, a proper system of drainage of the peat bog is essential. The water table must be kept far enough below the surface to protect the plants from excessive moisture; yet not too far so that they will not lack sufficient moisture and the soil will not undergo rapid decomposition. The climate controls to a large extent the depth to which the water table must be lowered. For good crops in regions with a cool climate, the water table is kept from 12 to 40 inches below the surface.

Peat nitrogen is rather inert; hence many peats require the addition of small amounts of available nitrogen; when active decomposition sets in, especially in the case of lowmoor peats, considerable nitrogen may be made available to the growing crops. Peat is most deficient in potash and phosphorus, and in the case of very acid peats, in lime. Applications of these is highly essential for the growth of most crops. In

TABLE 2.—Chemical Composition of Florida (Everglades) Peat Profile (Waksman and Stevens) on Per Cent Basis of Dry Material.

Number	Peat Formation	Depth of Layer cm.	Ash	Crude Protein	Ether Soluble	Cold and Hot Water Soluble	Alcohol Soluble	Hemi-cellulose	Cellulose	Lignin	Total
50	Surface layer	0-6.5	12.09	22.75	2.96	1.31	1.22	6.87	0.30	43.72	91.22
51	Upper fibrous layer	6.5-26	10.00	23.06	2.98	1.73	1.06	6.41	0.28	46.12	91.64
52	Typical saw-grass peat	26-40	6.86	22.25	3.16	1.60	1.31	8.04	0.43	44.90	88.55
53	Lower fibrous layer	40-50	8.05	21.25	3 21	1.45	1.39	7.63	0.43	47.63	91.04
54	Sedimentary layer	50-62	59.60	9.00	2.97	1.07	0.45	2.19	0	19.33	94.61
55	Lower portion of sedimentary layer	62-70	42.37	12.98	1.46	0.82	0.68	2.64	0	28.47	89.42
56	Lower fibrous layer	110-120	15.14	20.38	1.58	0.84	1.23	4.30	0	48.44	91.91

TABLE 3.—Evolution of CO_2 and Formation of Nitrate from Different Layers of an Everglade Peat Profile, Using 25-gm. Portions of Dry Material and 200 Per Cent Moisture.

Number of Layer	Total CO_2 Evolution (MGM. C)				Nitrogen Liberation in 32 Days (MGM.)		
	5 Days Incubation	12 Days Incubation	26 Days Incubation	32 Days Incubation	NH_3	NO_3-N	Total N
50	11.5	23.9	44.6	54.8	4.82	13.20	18.02
52	16.9	28.6	44.4	51.8	2.45	23.24	25.69
54	3.8	7.0	13.6	15.7	1.25	5.70	6.95
56	2.9	6.7	16.2	21.1	1.20	3.45	4.65

TABLE 4.—Chemical Composition of a Lowmoor Peat Profile from Newton, N. J. (Waksman and Stevens).

Depth of Peat cm.	Original Moisture	Reaction pH	Per Cent Basis of Dry Material					
			Ether-soluble Fraction	Water-soluble Fraction	Hemicelluloses[1]	Lignin	Protein	Ash
12	78.7	5.9	0.66	3.08	10.31	38.35	22.48	13.22
80	86.6	6.3	1.10	1.24	8.95	50.33	18.72	10.13
160-180	90.5	6.3	0.49	2.31	7.02	57.83	14.81	10.15
160	86.2	6.7	0.78	1.14	7.51	42.10	19.81	15.00
Lake Peat	88.1	6.8	0.67	0.81	12.14	33.25	19.38	24.87
Sedimentary Material	80.9	8.0	0.36	1.24	5.92	15.62	9.81	59.55

[1] No true cellulose in any of the layers.

general, the fertilizer requirements of different types of peat vary considerably. Very often, peat will benefit considerably from the application of certain trace elements, notably copper.

A freshly drained peat bog benefits considerably by the application of farmyard manure. The preference of the latter to mineral fertilizers may to a certain extent be due to other substances being present in the manure than those added in the fertilizers.

The best crops to grow on peat soil are those which consume a large quantity of water. Some of the crops, however, may be sensitive to an over-supply of water, particularly the root crops, such as beets, rutabagas and carrots. Though a heavy growth might be produced on the higher water levels, the moist soil promotes the growth of lateral roots and the formation of "fingers."

Use of peat for soil improvement. The importance of humus in increasing the water-holding capacity of the soil, in improving aeration and generally loosening the soil, in retaining the plant nutrients, in favoring a proper tilth, and in improving in various other ways the soil as a medium for plant growth is now generally recognized. Stable manure has always been used to supplement the residues left from the growth of crops. However, in view of the fact that the supply of farmyard manure available for soil improvement is continuously diminishing, peat is frequently found a ready substitute. It is used either as such or is supplemented with inorganic fertilizer, when required. Peat may be added either directly to the soil or after preliminary composting with minerals, with soil, with farm manure and with plant residues.

The use of different forms of peat is receiving particular attention in the greenhouses, and on lawns and golf courses. It is employed as a source of organic matter and as an ingredient in top soil and for top-dressing, as well as for the improvement of soil texture; favorable results have been obtained when one-fourth to one-half of the total volume of the soil is peat, with the addition of manure or fertilizer as a means of overcoming the deficiency of soluble plant-food constituents.

In view of the fact that peats do not carry any available phosphorus and potash and only limited amounts of available nitrogen, these nutrients have to be supplemented by the use of commercial fertilizer. The peat should be thoroughly mixed with the surface of the soil (upper $^3/_4$ inches) and should not be allowed to remain in layers.

Use of peat as a litter. The use of peat litter for stable bedding has found extensive application in Europe for over a century. In this respect, peat litter, considered as an excellent litter for stables and poultry houses, was distinguished from peat mull, a powdery or dusty material obtained when peat litter is sifted. The latter is used for addition to closets, for purifying and deodorizing sewage, and as a general absorbent. The peat best suited for this purpose is light, incompletely decomposed peat moss. This type of peat occur sometimes in thin layers in the black or brown heather peat of lowmoors and fens. The chief sources of moss peat suitable for peat litter are the highmoor peat bogs of northern Europe and in the northeastern and northwestern parts of the United States and Canada. The determining circumstances for the use of peat are the demand and market prices of various litters, account being taken of the fact that the absorptive powers of other litters are considerably smaller than those of peat: in the case of straw, this absorptive power is only 200 to 350 per cent, of saw-dust 360 to 500 per cent, as compared to about 800 to 1000 for peat moss. The litter is spread to a depth of 4 to 8 inches. For every square yard of stable floor, about 20 pounds of peat are required. The fully saturated litter is removed and replaced by 2 to 4 kilos of fresh litter for each animal (4 to 6 pounds in the case of horses). A bed lasts 4 to 5 weeks in the case of horses and 2 to 3 weeks in that of cattle. Sewage channels in the stalls are filled with peat litter to prevent the urine from flowing away, which absorbed by the peat, makes an excellent manure.

In the case of poultry houses, where the floors are covered with peat dust, diseases are said to be unknown. Peat is also excellent for making

nests. The fowls scratch the material in search of grain, thus keeping themselves clean and healthy. The droppings are soon worked up into a powder and mixed with the vegetable matter of the peat dust so that the resultant manure becomes valuable for the garden, being rich in readily available nitrogenous compounds.

Uses of peat in horticulture and for mulches. In a finely shredded condition, peat has a variety of applications in horticulture. It is used as a medium for germinating seeds, to start cuttings, to transplant and grow evergreens and shrubs, and to propagate rare orchids. As a mulch it protects plants and soil, especially in case of evergreen trees, shrubs and certain herbaceous perennials, against the effects of alternate freezing and thawing, and keeps down weeds. For acid loving plants peat moss is best used.

Lowmoor peat is more valuable than sphagnum peat for incorporation in soil and for potting plants. In some instances, the application of small amounts of salts of copper, iron, and manganese results in stimulating the growth of plants on peat. Peat is, for many plants, a very favorable medium for root formation. It has been used for rooting various hardwood and softwood cuttings and was found to be superior to sand and to various fibers for this purpose. Strawberry runners also root readily in peat.

Peat has also found extensive application in forest nurseries. Peat having a pH 5.5 or less is most desirable, especially for raising coniferous stock. A pH of 6.0-7.0 may be satisfactory for hardwood nurseries, but it is undesirable for nurseries raising coniferous seedlings because of the danger of damping-off and other infectious diseases. Peat having a reaction higher than pH 7.0 is unsatisfactory because of the danger of diseases and direct toxicity of carbonates. A nitrogen content in the peat of about 2% was believed to be very satisfactory for the growth of nursery stock (Wilde and Hull).

Laurie found that for many greenhouse plants, including chrysanthemums, greater beneficial results were obtained from adding peat as a mulch, rather than from incorporating it with the soil. Sedge peat was found to be more effective in this connection than sphagnum peat, unless this was used in conjunction with nitrogenous fertilizers. A subsequent dressing of superphosphate proved to exert a favorable effect. These results were ascribed to the fertilizing action of the peat. As a mulch, out of doors, it was found useful in discouraging weeds, and in counteracting the effects of thawing or freezing.

The type of peat to be employed in different cases is thus found to be highly specific. The value of peat may be calculated on a moisture-free and ash-free basis. Forest peat is occasionally employed for mulching purposes and for soil improvement, when moss and sedge peats are not available. Peat soil or peat humus may be used for surfacing newly built lawns and for improving generally the physical condition of the soil.

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BANQUET AND BUSINESS MEETING

R. V. Allison, Presiding

Following the banquet held in the Assembly Hall of the Student Union, a business meeting was called at 8:15 P. M.

READING OF THE MINUTES

The reading of the minutes of the organization meeting held in Hollywood (Florida) in April, 1939, was dispensed with on motion and second from the floor following reference by Mr. R. A. Carrigan, Secretary, to the fact that the full Proceedings covering same was ready for the mail.

APPOINTMENT OF AUDITING COMMITTEE

An auditing committee consisting of F. B. Smith, Chairman, G. H. Blackmon, and R. B. Becker was appointed by the Chair with instructions to examine the financial records of the Society at a time of mutual convenience and report.

REPORT OF STANDING COMMITTEES

The review and discussion of the setup of subject matter committees at the time of the Tampa meeting on April 2 was considered and approved. The various committee reports, most of them extemporaneous, are summarized as follows:

1. *Membership Committee, R. A. Carrigan, Chairman*

   Mr. Carrigan discussed briefly the fine record of cooperation and accomplishment during the year in developing a substantial membership in the Society and called attention to the fact that the published roster in the First Proceedings listed a total of 375 names.

2. *Soil Survey Committee, Mr. George F. Westbrook, Chairman*

   In the absence of the Chairman or any member of the Committee, the report of this important group was deferred until the next meeting with the understanding that the Secretary of the Society would remind them of the need for drafting a soil survey bill in good time to be widely publicised and discussed before being brought before the 1941 Legislature for enactment into law.

3. *Methods of Analysis Committee, L. H. Rogers, Chairman*

   A general plan of work for the coming year was outlined, the main objectives of which were the reviewing of physical and chemical methods in use in soils research in the State at the present time and the development of a coordinated plan of study and testing of others in the order of their importance.

4. *Terminology Committee, Michael Peech, Chairman*

   In accordance with the plans formulated at the last annual meeting, a number of terms covering the fields of soil chemistry, soil physics, soil microbiology, soil classification, and soil fertility have been tentatively selected and defined. It is quite probable that in the revision some addditions and omissions will be made before the adoption of the final draft for publication in the next issue of the Proceedings. The Committee has proposed to prepare a preliminary report in mimeographed form listing the defined terms to be dis-

tributed to the members of the Society for consideration at the next annual meeting with a request that suggesttions and criticisms offered by the membership be mailed to the Chairman of the Committee not later than one month following the meeting.

5. *Research Committee, L. W. Gaddum, Chairman*

The development of a sound soils research program that is fully and comprehensively integrated with related fields of effort was stressed as the most important responsibility of the committee. The vital relationship of such a program to teaching, on the one hand, and extension, on the other, was also emphasized as was likewise the fertile field for contact with Tropical American workers through the Tropical Soils Committee, or otherwise.

6. *Soil and Water Conservation Committee, Geo. B. Hills, Chairman*

The principal thought that has been given by this committee to its broad field of responsibility in the preliminary discussions that have been held have related largely to the highly important problem of soil and water conservation in the Everglades. This has been largely with the thought of localizing the problems of this area to the extent that a sub-committee might be set up for the purpose of stimulating research and organizing educational meetings, with the view of discussing basic methods of approach to the vital, overall, long-time planning that is so badly needed in handling an area so large and so involved with such a great variety of problems relating to water control and soil conservation and use.

7. *Fertilizer Recommendations Committee, W. L. Tait, Chairman*

The principal activities of this group to date have been a courageous sizing up of the field of their responsibility with the consequent thought of dividing it into at least four sub-committee groups on the basis of plant interests, namely: Field Crops, Truck Crops, Citrus, and Miscellaneous Horticultural Crops.

8. *Teaching Committee, F. B. Smith, Chairman*

Drs. H. L. Knowles and A. P. Black of the Departments of Physics and Agricultural Chemistry, respectively, at the University of Florida, were appointed to the Teaching Committee during the year. The field of responsibility of the Committee was acknowledged as extending all the way from classwork on the high school or vocational agriculture level through the undergraduate curriculum of the University to training on the graduate level.

9. *Extension Committee, Ed L. Ayers, Chairman*

The membership of the Committee has been developed to include M. U. Mounts, L. H. Alsmeyer, R. E. Norris, J. W. Malone, and Colin Gunn. The first step would appear to be the establishment of a comprehensive contact, by questionnaire or otherwise, with all County Agricultural Agents in the State to ascertain their opinions on the soils problems of their various counties with the view of using this information, as far as possible, in setting up an effective soils extension program.

10. *Tropical Soils Committee, H. H. Bennett, Chairman*

In a brief discussion of tropical soils last evening, at the time of the dinner and smoker, Doctor Bennett outlined, in very emphatic terms, the need for research on tropical soils and the great benefit that could be developed through a closer coordination of our interest and work in this field with the innumerable problems of our Latin American neighbors in the vast tropical regions to the south. It was especially emphasized that there were few ways in which the spirit of the good neighbor could be brought to the front more forcefully and more effectively than in the field of soil and plant relationships. Our defense needs in the fields of rubber, quinine, etc., were also stressed.

11. *Forest Relationships Committee, H. S. Newins, Chairman*

The very definite interest of the staff of the School of Forestry in the manifold relationships of soils to plants under forest conditions was emphasized by Prof. Newins as was also their desire to cooperate in the work of the Soil Science Society in every possible way, whether as individuals or as a group.

The field of the Committee was outlined briefly and future possibilities suggested for contact with tropical forestry through mutual interest in the field of soil and plant relationships.

The Chair was requested to give definite consideration to the substitution of the name of Prof. R. H. Westveld as Chairman of the Committee and the request was granted and supported by motion and second from the floor.

12. *Animal Relationships Committee, R. B. Becker, Chairman*

The paper presented by Dr. Becker and Mr. Henderson in the course of the morning symposium on trace elements might well be regarded as the first report of this committee, since it indicates in such a complete and comprehensive manner the vital relationships of the animal to the soil through the medium of the plant.

13. *Human Relationships Committee, Chester F. Ahmann, M.D., Chairman*

As in the case of the Committee on Animal Relationships, the paper presented in the symposium on trace elements this morning by Dr. Ouida D. Abbott and Dr. C. F. Ahmann under the title "Human Relationships" might well be regarded as a first report by the committee carrying the same title as the paper.

ELECTION OF OFFICERS

The nominating committee appointed by the President at the close of the morning's meeting, consisting of Dr. L. W. Gaddum, Chairman, Waldo E. Sexton, and Dr. J. R. Neller was requested to report.

The committee nominated a single candidate in the person of Dr. F. B. Smith, as Vice-President for the ensuing year and moved that the nominations be closed and the Secretary be instructed to cast a unanimous ballot for the nominee. This was promptly seconded and unanimously carried by a vote of ayes.

INSTALLATION OF OFFICERS

Following the election, Vice-President Peech was inducted into the office of President and in the course of a brief speech on the prospective program of the Society for the coming year, announced that the Standing Committees would continue in their various fields of responsibility without change.

RESIGNATION OF THE SECRETARY-TREASURER

The resignation of the Secretary-Treasurer of the Society, Mr. R. A. Carrigan, was announced. The action was accepted by President Peech with regret in view of the splendid service rendered by Mr. Carrigan during the first year of the Society's existence. The appointment of R. V. Allison, by action of the Executive Committee, to fill the position of Secretary-Treasurer of the Society was announced by the President; an action which automatically created a vacancy on the Executive Committee of the Society for the coming year.

ELECTION OF A MEMBER FOR THE EXECUTIVE COMMITTEE

For the purpose of filling the vacancy on the Executive Committee created by the appointment of the retiring President to the position of Secretary-Treasurer, President Peech asked the members of the nominating committee to continue in this responsibility and bring appropriate nominations to the floor as soon as possible. Following a brief retirement, the committee returned with the single nomination of Mr. H. C. Hendricksen of Eustis who had served, by election, as fourth member on the committee during the past year. By motion and second from the floor, nominations were promptly closed and by a unanimous vote of ayes the Secretary was instructed to cast a unanimous ballot for Mr. Hendricksen.

There being no new business, the meeting adjourned at 9:50 P. M.

REPORT OF THE TREASURER TO THE AUDITING COMMITTEE AS OF JUNE 12, 1940

RECEIPTS

Dues collected for 1939	$413.00
Dues collected for 1940	84.00
Sustaining memberships	225.00
Total	$722.00

DISBURSEMENTS AND CASH ON HAND

Total expenditures*	$172.37
Balance, First National Bank, Gainesville	544.63
Cash and undeposited checks on hand	5.00
Total	$722.00**

Examined and approved by the Auditing Committee.

Signed:
G. H. BLACKMON
R. B. BECKER
F. B. SMITH, *Chairman*

* Itemized in the records with receipts and examined by the Committee.

** Includes balance of unpaid bill for publishing First Proceedings of the Society estimated at $300.00.

MEMBERSHIP LIST

In view of the length and prospective cost of the present proceedings the publication of the complete membership list has been omitted this year but will be brought fully up to date in the Third Proceedings. This will include separate lists of sustaining memberships held by individuals as well as by associations or companies.

—EDITOR

R. V. Allison

R. A. Carrigan

OFFICERS OF THE SOCIETY
1939-1940

R. V. Allison ..... President
Gainesville

Michael Peech ..... Vice-President
Lake Alfred

Henry C. Henricksen* ..... Member Executive Committee
Eustis

Richard A. Carrigan ..... Secretary-Treasurer
Gainesville

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* Henry C. Henricksen was reelected to serve another year as a member of the Executive Committee.